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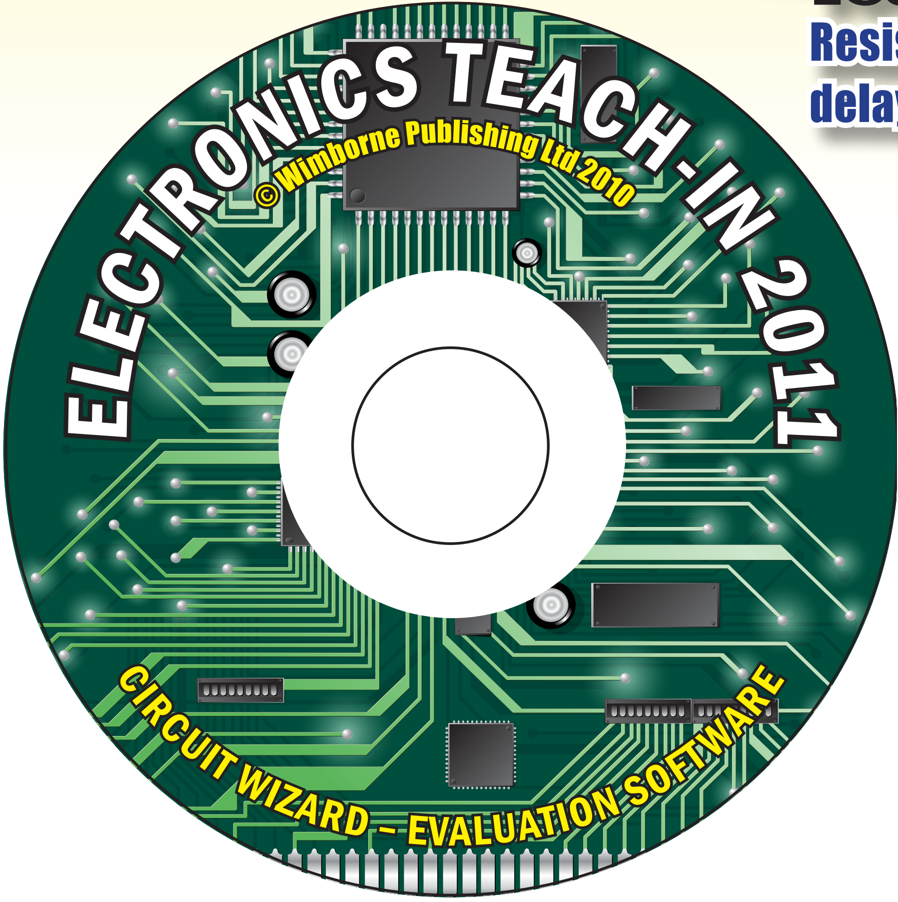

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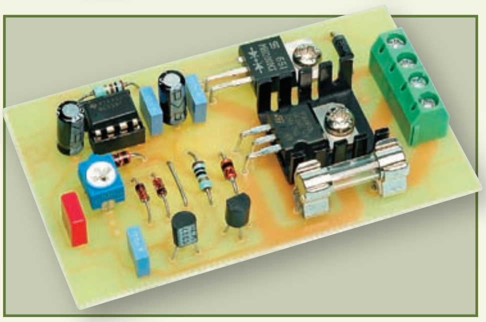

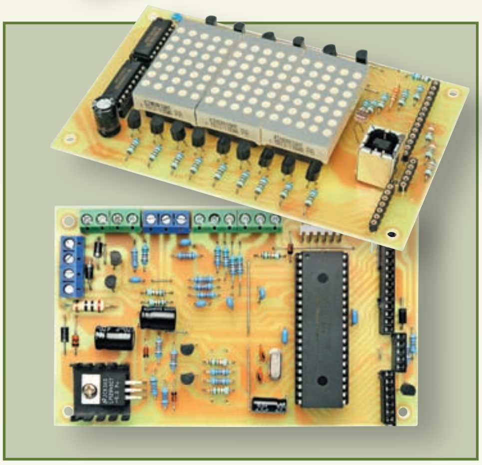

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Our January 2011 issue will be published on Thursday 9 December 2010, see page 80 for details.

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EVERYDAY PRACTICAL ELECTRONICS
FEATURED KITS

Everyday Practical Electronics Magazine has been publishing a series of popular kits by the acclaimed Silicon Chip Magazine Australia. These projects are 'bullet proof' and already tested down under.
All Jaycar kits are supplied with specified board components, quality fibreglass tinned PCBs and have clear English instructions. Watch this space for future featured kits.

December 2010

PROGRAMMABLE HIGH ENERGY IGNITION KIT

KC-5442 £27.75 plus postage & packing
This advanced and versatile ignition system is suited for both two & four stroke engines. Used to modify the factory ignition timing or as the basis for a stand-alone ignition system with variable ignition timing, electronic coil control and anti-knock sensing.

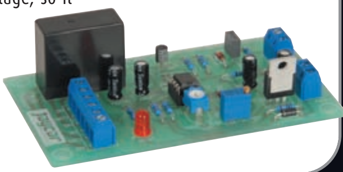
- Timing retard & advance over a wide range
- Suitable for single coil systems
- Dwell adjustment
- Single or dual mapping ranges
- Max & min RPM adjustment

Featured in EPE September / October / November 2009

UNIVERSAL VOLTAGE SWITCH

FEATURED THIS MONTH

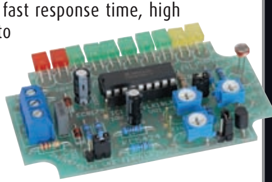
KC-5377 £9.75 plus postage & packing
This is a universal module which can be adapted to suit a range of different applications. It will trip a relay when a preset voltage is reached. It can be configured to trip with a rising or falling voltage, so it is suitable for a wide variety of voltage outputting devices eg., throttle position sensor, air flow sensor, EGO sensor. It also features adjustable hysteresis (the difference between trigger on/off voltage), making it extremely versatile. You could use it to trigger an extra fuel pump under high boost, anti-lag wastegate shutoff, and much more. Kit supplied with PCB, and all electronic components.



- PCB Dimensions: 105 x 60mm

VOLTAGE MONITOR KIT

KC-5424 £6.75 plus postage & packing
This versatile kit will allow you to monitor the battery voltage, the airflow meter or oxygen sensor in your car. The kit features 10 LEDs that illuminate in response to the measured voltage, preset 9-16V, 0.-5V or 0-1V ranges, complete with a fast response time, high input impedance and auto dimming for night time driving. Kit includes PCB with overlay, LED bar graph and all electronic components.



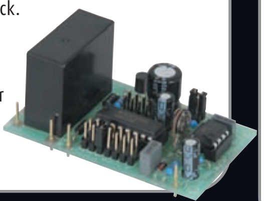
- 12VDC
- Recommended box: UB5 use HB-6015 £

Featured in EPE November 2007

THE 'FLEXITIMER'

KA-1732 £6.00 plus postage & packing
This kit uses a handful of components to accurately time intervals from a few seconds to a whole day. It can switch a number of different output devices and can be powered by a battery or mains plugpack.

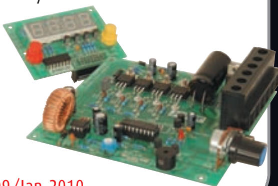
- Kit includes PCB and all components
- Requires 12 - 15 VDC power



Featured in EPE May/June 2008

12-24V HIGH CURRENT MOTOR SPEED CONTROLLER KIT

KC-5465 £26.25 plus postage & packing
Controls a 12 or 24VDC motor at up to 40A continuous and features automatic soft-start, fast switch-off and a 4-digit display to show settings. Speed regulation is maintained even under heavy loads and the system includes an overload warning buzzer and a low battery alarm. Kit contains PCB and all specified electronic components.



Featured in EPE Dec 2009/Jan 2010

FULL FUNCTION SMART CARD READER / PROGRAMMER KIT

KC-5361 £16.00 plus postage & packing
Program both the microcontroller and EEPROM in the popular gold, silver and emerald wafer cards. Card used needs to conform to ISO-7816 standards. Powered by 9-12 VDC wall adaptor (use MP-3030 £7.00)or a 9V battery. Instructions outline software requirements that are freely available on the internet. Kit supplied with PCB, wafer card socket and all electronic components.

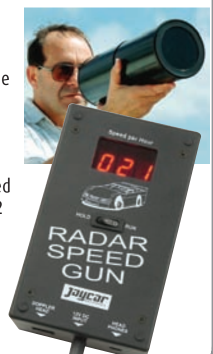
- PCB measures: 141 x 101mm

Jaycar Electronics and Silicon Chip Magazine will not accept responsibility for the operation of this device, its related software, or its potential to be used for unlawful purposes.

Featured in EPE May 2006

RADAR SPEED GUN KIT - MKII

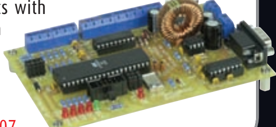
KC-5441 £29.00 plus postage & packing
If you're into any kind of racing like cars, bikes boats or even the horses, this kit is for you. The electronics are mounted in the supplied Jiffy box and the radar gun assembly can be made simply with two coffee tins fitted end to end. The circuit needs 12 VDC at only 130mA so you can use a small SLA or rechargeable battery pack. Kit includes PCB and all specified components.



Featured in EPE January 2009

SMS CONTROLLER MODULE

KC-5400 £17.00 plus postage & packing
Control appliances or receive alert notification from anywhere. By sending plain text messages this kit will allow you to control up to eight devices. At the same time, it can also monitor four digital inputs. It works with old Nokia handsets such as the 5110, 6110, 3210, and 3310, which can be bought inexpensively. Kit supplied with PCB, pre-programmed microcontroller and all electronics components with manual. Requires a Nokia data cable which can be readily found in mobile phone accessory stores.



Featured in EPE March 2007

KNOCK SENSOR

KC-5444 £5.50 plus postage & packing
Add this option to your KC-5442 Programmable High Energy Ignition system and the unit will automatically retard the ignition timing if knocking is detected. Ideal for high performance cars running high octane fuel. Requires a knock sensor which is cheaply available from most wreckers. Kit includes PCB with overlay and all specified components.

Featured in EPE December 2009

ULTRA-LOW DISTORTION 135WRMS AMPLIFIER MODULE

KC-5470 £27.75 plus postage & packing
This ultra low distortion amplifier module uses the new ThermalTrak power transistors and is largely based on the high-performance Class-A amplifier which was featured in SILICON CHIP during 2007. This improved circuit has no need for a quiescent current adjustment or a Vbe multiplier transistor and has an exceptionally low distortion figure. Kit supplied with PCB and all electronic components. Heat sink and power supply not included.

Output Power: 135WRMS into 8 ohms
and 200WRMS into 4 ohms
Frequency Response at 1W: 4Hz to 50kHz
Harmonic Distortion: <0.008% from 20Hz to 20kHz

Also available:
Power Supply Kit for Ultra-LD Mk2 200W Amplifier (KC-5470) - KC-5471 £16.25

KC-5471

KC-5470

Featured in EPE August / September 2010

HAPPY CHRISTMAS TO ALL!

To all EPE readers, our best wishes this holiday season from Jaycar Electronics Team

Jaycar Electronics

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Cheaper software on the cards?

On 20 October, Apple previewed a few features of the next iteration of their computer operating system. Interesting news for those of us who use their machines, but perhaps a big 'so what?' for the vast majority of the planet who prefer to use Microsoft Windows. A reasonable reaction on the face of it, but one item caught my eye, and it could be important for all computer users.

Apple are going to set up an 'App Store' for their desk and notebook computers along similar lines to their successful mobile devices (iPhone, iPod and iPad). Why is this important? Well, what it could herald is a revolution in how people buy their software – and how much it costs. One of the key features of the iPhone App Store is its cheapness; in fact, many good apps are completely free. It has brought true competition to a segment of the market, and there is no reason why it cannot work for conventional computers. Much of the software is so cheap that it can be bought on a whim. While a business model like this is unlikely to offer Adobe Photoshop for a few pounds, it may well force down prices, which would be good for consumers.

Apple are not only ambitious, but they also manage to punch well above their weight in terms of how they influence the rest of the industry. Consider one statistic; remember when Apple's iPhone came out just two and a half years ago? It was their first ever mobile phone, but within two years, despite only having 3% of the market they were taking 39% of the profits. Apple now makes considerably more money from mobile phones than Nokia, Samsung and LG – combined.

The big question is have they spotted the future in terms of software sales? It will be fascinating to watch.

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NEWS

A roundup of the latest Everyday News from the world of electronics

Music and video piracy on the rise By Barry Fox

'Pirates are fast, agile and creative and they don't play by a lot of rules. They are also pretty organised,' warns Richard Atkinson, who spent six years with Walt Disney and now runs his own consultancy, Anti-Piracy Worldwide, which studies the 'business problem' of piracy.

Atkinson was talking at the *Futuresource Entertainment Retailing and Supply Chain Conference* in London, in late September.

'If the new Tron Legacy movie got out one day early' he estimates 'it would mean a loss of $126 million in theatrical and home entertainment sales'.

'It's a myth that limiting a release by language limits piracy' he said, showing pirate clips of Cars dubbed and subtitled into English, French and Spanish. 'The pirates can do that in 24 hours.'

'Visibly watermarking movies is not enough, either' he said, using pirate clips of Wall-e to show how pirates now mask out time code with a fuzzy overlay. 'And all the pirate disc and download copies of Wall-e sold round the world came from just ten source copies.'

One problem for the industry is that while new formats like Blu-ray offer ever-improving quality, the mass market is becoming content with compromised sound and pictures.

Martin Talbot, managing director, the Official Charts Company, which tracks UK music sales, notes that over the past six years the music sector has undergone a huge transformation. '98.4% of singles are now sold digitally. But 85% of albums are still physical sales – after an all-time high in 2004.'

'One thing we see is that quality isn't paramount. People download MP3 and AAC files and listen on tinny inner ear headphones. The power of inventory and catalogue is important. People like to snack and cherry pick from the long tail. Video streaming is also growing, despite the poor quality.'

At another conference in London earlier in the year, organised by Rovi (formerly the copy protection specialists Macrovision) colourful details had emerged of the industry's running technical battle with people who 'rip' movies from discs and digital stores.

Says Colin Dixon, senior analyst at research company TDG Diffusion: 'Despite P2P file-sharing, disc copying continues. Rent and rip is rampant. 25% of copiers are ripping DVDs, 50% Blu-ray discs (BD), probably because of the price difference.

'People who rent and rip are on average making 2.89 additional copies. Around 30% share with family, friends and colleagues'

'In 2008, there were just two BD ripping programs. Now there are six. If you think the size of the file is a barrier to BD ripping, you are wrong.'

'BD's AACS copy protection is stronger than DVD's CSS, but the key needed to rip *Avatar* was available before the BD was released. The movie *X-Men* was available for free download before theatrical release.'

TDG's research shows clearly that people who really want to rip, will find a way of ripping. But as Colin Dixon puts it: 'Copying is very time-consuming, so failure when you try to copy a disc is painful. Making it difficult is the main goal.'

Microsoft showcases Windows Phone 7

Microsoft has officially unveiled its Windows Phone 7 operating system, along with nine new handsets from a variety of manufacturers that will run the new OS. Windows Phone 7 saw its first introduction back in February. 'We have a beautiful line-up in this first wave of Windows Phone 7 handsets,' said Steve Ballmer, chief executive officer at Microsoft. 'Microsoft and its partners are delivering a different kind of mobile phone and experience – one that makes everyday tasks faster by getting more done in fewer steps and providing timely information in a 'glance and go' format.'

Microsoft declared that the goal for their latest smartphone OS is an ambitious one: to deliver a phone that truly integrates the things people really want to do, puts those things right in front of them, and either lets them get finished quickly or immerses them in the experience they were seeking.

Centered around 'hubs' that allow users to quickly see a variety of pieces of information related to such topics as people, music, photos, and office, Windows Phone 7 will also accommodate third-party apps such as Twitter, eBay and a library of gaming titles from EA, in addition to apps from smaller developers facilitated by Microsoft's developer program for the platform.

In a departure from the icon-focused user interface used by Apple and others, Microsoft has chosen to use a flowing interface of flexible 'tiles' that can each represent various pieces of information depending on the type of data required to be presented. You can view a demo of the new mobile OS at: **http://tinyurl.com/36x36ng**

Google Earth time machine

Few events in human history have the scale of World War II. Its spatial breadth and temporal extent make it difficult to comprehend by those of us too young to have lived it. There are history books, movies, and photographs, but they portray isolated places and events more than the connected whole. Google has tried to address this by launching historical imagery in Google Earth in a number of new areas, including London in 1945, in coordination with archivists.

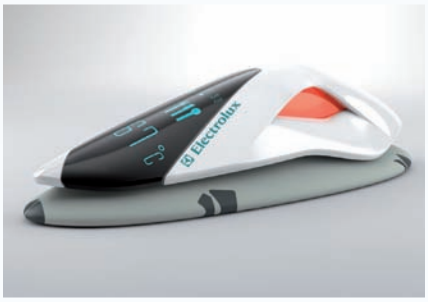
This newly published data shows clearly the reality of everyday life back then — bombed buildings, deprivations, militarisation, and the normal appearance of what were then secret facilities. In London, you can view the Map Room, from where Winston Churchill and his wartime cabinet led Britain to victory through perseverance, and of course, maps.

Nearly all of 1945 London is available for exploration, and enjoying it is easy. Just start Google Earth (you can install it from **http://earth.google.co.uk** if you're not one of the 700 million who already have) and type London as your destination in the upper left. Then, click on the clock icon to enable historic imagery. Scroll back to 1945, and feast your eyes on imagery like the intersection of The Cut and Short Streets near Waterloo station showing the bombed/cleared area that is now the Young Vic theatre.

Turning back 66 years of visual history is also possible in war-time Paris. Here, you can see monuments to Napoleonic-era victories during wartime occupation, and study scenes of everyday life in those historic times.

Historical imagery is also already available for several other cities in Europe. Last year, Google published photos depicting, both pre- and post-war Warsaw. In 1935 we see a vibrant city full of people, but in 1945 we are witness to the destruction of 85% of the buildings, along with palaces and bridges.

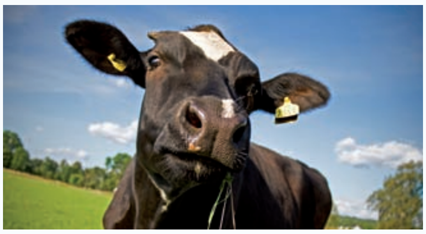
Move over fridge magnet – it's time for the pan magnet



Imagine an induction hob condensed to the size of a mobile phone and transformed in shape till it looks like a sleek mini-iron that can then be stuck to the side of a metal pan to heat up the contents.

That is the idea that *Electrolux Design Lab 2010* winner Peter Alwin from the National Institute of Design in India came up with when he designed the The Snail, the Micro Induction Heating – a portable form of induction heating that can stick onto the side of pots, pans or mugs to heat the contents up using magnetic induction.

Rural 'superfast' broadband



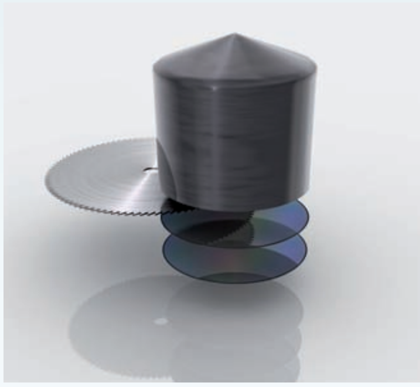
Four rural areas that include some of the most remote and geographically challenging parts of the UK have been selected to pilot the next generation of high speed broadband. Each area will be allocated around £5-10m from a total of £530m funding announced yesterday to support the roll-out of broadband between now and 2015 to areas that the market alone will not reach.

Parts of Cumbria, the Highlands and Islands, North Yorkshire and the Golden Valley in Herefordshire will all be connected at speeds only usually found in densely populated urban areas, the Chancellor announced in October's Spending Review. *'The pilot exercise will help establish the commercial costs and challenges involved in rolling out superfast broadband across the UK.'*

SAND-TO-SILICON

Ever wondered how the microprocessor, the brain 'behind the magic' of your PC is made? If so, then an Intel site is just for you. Including an animated video and high resolution images, the simple-to-follow documentation and graphics illuminate the fascinating process Intel employs in building the chips that power many of the world's computers. To access the explanation, visit: **www.intel.com/pressroom/kits/chipmaking/index.htm**

With about 25% (mass) silicon is – after oxygen –the second most frequent chemical element in the earth's crust. Sand – especially quartz – has high percentages of silicon in the form of silicon dioxide (SiO_2) and is the base ingredient for semiconductor manufacturing.



Once processed, the sand becomes a mono-crystal silicon ingot. An electronic-grade silicon ingot weights about 100 kilograms (=220 pounds) and has a silicon purity of 99.9999999%.

The ingot is cut into individual silicon discs called wafers. The thickness of a wafer is about 1mm.

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By JIM ROWE

Digital RF Level & Power Meter

Need to measure small signals at radio frequencies? Here is a low-cost digital level and power meter which will allow you to measure RF signals from below 50kHz to above 500MHz. As well as indicating the signal level in volts and dBV, it also shows the corresponding power level (into 50 ohms) in both milliwatts and dBm.

TRADITIONALLY, RF level/power meters have been quite expensive beasts costing hundreds of pounds, even secondhand. Small wonder that many of us have simply had to do without them. Such RF level/power meters have always been expensive because of the measurement technique they used: converting the RF energy into heat and then measuring the temperature rise using a sensitive thermocouple system.

Luckily for us, advancing semiconductor technology now provides an easier way: the wideband logarithmic amplifier/detector IC. Its DC output is closely proportional to the logarithm of the RF input voltage. We can achieve the desired result by combining one of these chips with an 'intelligent' metering circuit, capable of processing this logarithmic DC voltage to indicate both signal level and the corresponding power level.

In a nutshell, our circuit uses an Analog Devices AD8307AN logarithmic amplifier/detector to convert RF signals into DC, which is processed by a PIC microcontroller. The micro uses some fairly fancy maths routines to work out the signal level and power, which is then displayed on a standard 2-line LCD panel. The whole set-up works from a 9V battery or DC plugpack and draws less than 35mA.

The AD8307 log amp/detector

To help understand logarithmic amplifier/detector ICs, take a look at Fig.1. This gives a simplified view inside the AD8307AN device.

As shown, the incoming RF signals are passed through six cascaded wideband differential amplifier/limiter stages, each of which has a gain of 14.3dB (about 5.2 times) before it enters limiting (ie, clipping). This gives a total amplifier gain of about 86dB or about 20,000 times. The outputs of each amplifier/limiter stage are fed to a series of nine full-wave detector cells, along with similar outputs from three cascaded passive 14.3dB attenuator cells connected to the input of the first amplifier/limiter.

The differential current-mode outputs of all nine detector cells are added together and fed to a 'current mirror' output stage, which effectively converts them into a single-sided DC output current. Because of the combination of cascaded gain and limiting in

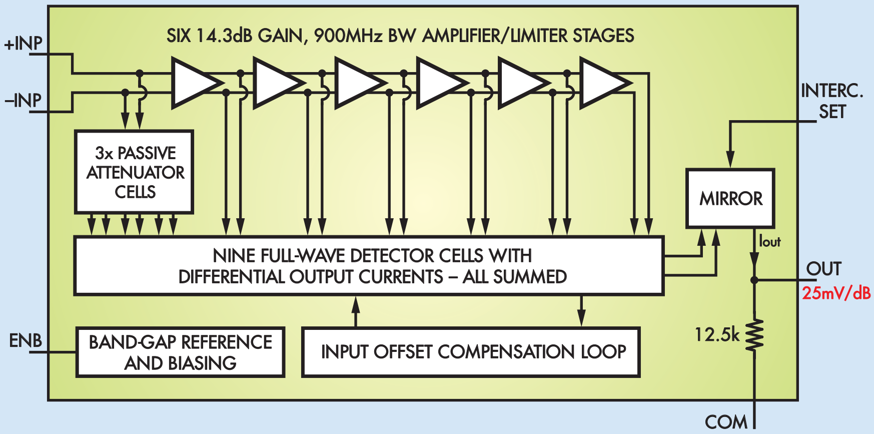
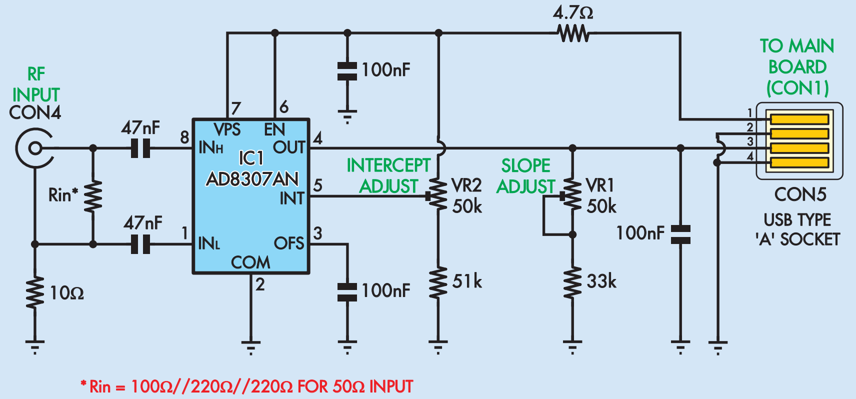


Fig.1: block diagram of the AD8307AN amplifier/detector IC. The incoming RF signals are passed through six cascaded wideband differential amplifier/limiter stages, and these in turn drive full-wave detector cells (see text).



RF LEVEL & POWER METER HEAD-END CIRCUIT

Fig.2: the head-end circuit is based on the AD8307AN. The incoming RF signals are fed to pins 8 and 1 via 47nF capacitors, while the detected output appears at pin 4 and is fed to pin 3 of a type A USB socket.

Specifications

- Input impedance: 50Ω (can be changed to 75Ω or 1.1kΩ)
- Measuring frequency range: from below 50kHz to above 500MHz
- Maximum input signal level: 2.238V RMS (+7.0dBV)
- Minimum input signal level: 22μV RMS (–93dBV)
- Maximum input power level: 100mW into 50Ω (+20dBm)
- Minimum input power level: 1nW (0.001μW/–60dBm)
- Measurement linearity: approximately ±0.3dB
- Measurement accuracy: approximately 0.2%
- Power requirements: 9V DC at 35mA (no backlight) or 120mA with backlight

the amplifiers (plus an internal offset compensation loop), the amplitude of this output current is closely proportional to the logarithm of the RF input voltage, over an input range of 100dB from about –93dBV (22.4μV) up to +7.0dBV (2.24V).

In fact, this 'logarithmic law' relationship is linear to within ±0.3dB over most of the range. The output current I_{out} increases at a slope of very close to 2μA per dB increase in RF input level. This current passes through an internal 12.5kΩ resistor, resulting in a DC output voltage which increases at the rate of 25mV/dB. This slope can be fine tuned using an adjustable external resistor in parallel with the 12.5kΩ internal resistor.

So what's that 'intercept set' input for? This allows us to adjust the DC offset in the output current mirror, which adjusts the effective 'zero level' point of the chip's output current and voltage, ie, the 'origin' from which the output slope rises. You can think of it as setting the detector's zero point.

Head-end circuit

It's desirable to separate the RF detector section from the rest of the meter circuitry, partly because it is the only section handling RF signals and partly because it has very high gain and is therefore susceptible to electromagnetic interference. The AD8307AN and its accompanying components are therefore mounted on a separate small 'head-end' board, which in turn is mounted inside a small diecast aluminium box, for shielding.

The circuit of this head-end section is shown in Fig.2 and involves little else apart from the all-important AD8307AN (IC1). The incoming RF signals are coupled into the inputs of IC1 via two 47nF capacitors, with R_{in} providing the desired 50Ω input termination. (R_{in} is a combination of paralleled surface-mount chip resistors, to give a value of 52.4Ω with very low parasitic inductance. As the input impedance of the AD8307AN is very close to 1.1kΩ, and this is in parallel with R_{in}, the resulting total input resistance is very close to 50Ω).

Trimpot VR1 and its 33kΩ series resistor are connected between the output (pin 4) of IC1 and ground (0V), so they are effectively in parallel with the 12.5kΩ resistor inside the chip itself. This allows the output slope of the detector to be fine tuned to a value of 20mV/dB, when the meter is calibrated.

Trimpot VR2 is used to adjust the DC voltage fed to pin 5 of IC1. This is the 'intercept set' input, so VR2 effectively becomes the detector's zero set adjustment.

The head-end section connects to the main meter unit via a standard USB cable. This cable carries the detector's output voltage to the main board via pin 3 of CON5 and also supplies IC1 with +5V power via pin 1.

Main circuit

The processing part of the circuit is shown in Fig.3. This is where the

Volts, dBV, Milliwatts and dBm

The RF Level and Power Meter described in this article gives four indications for every measurement: the RF input voltage (in volts or millivolts), the corresponding value in dBV, the corresponding power level in the meter's 50Ω input load (in milliwatts or microwatts) and the corresponding value in dBm. The voltage and power levels probably need no explanation, but we should perhaps explain the significance of the two decibel readings.

For many years, engineers working in the communications and RF fields have found it convenient to describe signal amplitude and power levels in decibels, because of the very wide ranges involved – from microvolts (μV) to kilovolts (kV), and from nanowatts (nW) to kilowatts (kW).

Because decibel scales are logarithmic, they make it easier to work with signals varying over such wide ranges. To describe the voltage gain of an RF amplifier in terms of decibels, for example, we simply take the base-10 logarithm of the voltage gain (V_{out}/V_{in}) and multiply this figure by 20. So a voltage gain of 10 corresponds to +20dB, a gain of 100 corresponds to +40dB, a gain of 1000 corresponds to +60dB and so on.

Similarly an attenuator which reduces the voltage level by a factor of 10:1 can be described as having a 'gain' of –20dB. Get the idea?

When we're describing power levels rather than voltage, the power gain of an RF amplifier can be found by again taking the base-10 logarithm of the power gain (P_{out}/P_{in}) but this time multiplying the figure by 10. So a power gain of 10 times is +10dB, while a power gain of 100 times is +20dB and so on. (If you're a bit puzzled by the difference between voltage and power when calculating the decibels, it's merely because power increases with the square of the voltage. That's why we multiply the log of voltage ratios by 20 but we only multiply the log of power ratios by 10).

dbV and dBm

So what's the difference between 'dBV' and 'dBm' figures? Well, these are both decibel scales, but in this case they are used to compare one specific voltage or power level with a known reference value, rather than to compare two specific values. So the contractions dBV and dBm indicate that the figures they accompany are absolute, rather than relative.

'dBV' is a voltage level expressed in decibels with reference to 1.000 volts. So +6dBV (2V) is 6dB greater than 1V, while –20dBV (100mV) is 20dB smaller than 1V. So expressing a voltage in dBV merely indicates that it is measured on a decibel scale which refers to 1.00V as its 0dB point.

Similarly, 'dBm' is a power level which is expressed in decibels with reference to a specific reference power level of 1mW (milliwatt); in other words, on a decibel scale where 1mW corresponds to 0dB. So +10dBm corresponds to 10mW, +20dBm to 100mW and –30dBm to 1μW (microwatt).

There is another 'absolute' decibel scale used for expressing voltage levels, the dBμ scale. This refers to a level of 1μV (microvolt) as its 0dB point. So +120dBμ is the same as 0dBV, while 0dBu is the same as –120dBV.

One last point: since the dBV and dBm scales are 'absolute', surely they can be related to each other? Yes they can, but to work this out you need to know the impedance level – because that is what relates voltage and power in any circuit.

In most RF work, the impedance level is 50Ω. At this level, a voltage of 1V corresponds to a power level of 20mW ($1^2/50$), so 0dBV equals +13dBm. On the other hand –30dBm (= 1μW) corresponds to 7.07mV, or –43dBV. In other words, there's a fixed 13dB difference between the two scales.

This difference changes with impedance level, though. For example when the impedance level is 600Ω, 0dBm or 1mW corresponds to 0.7746V or –2.218dBV, so there's a fixed 2.2dB difference between dBm and dBV.

Older RF level and power meters often indicated in just dBm or perhaps in dBV as well. If the user wanted to know the actual voltage and power level, they had to either refer to a chart or grab a calculator and work them out. This could be pretty tedious, and that's why we've given this new RF Level and Power Meter the ability to calculate and display not just dBm and dBV, but the equivalent volts and milliwatts as well, for every measurement.

real 'work' is done, by the firmware running inside the PIC16F88-I/P micro (IC3). The PIC16F88-I/P device is well-suited to this application, as it includes an analog-to-digital converter (ADC) module with 10-bit measuring resolution. The ADC is also flexible in terms of its operating mode, with a choice of positive and negative reference voltages and also a 7-channel input multiplexer.

We take advantage of these features by using a positive reference voltage of 3.50V, which is fed into pin 2 of IC3 and by using three of the ADC input channels to allow firmware selection of the measuring range via pin 1 (AN2), pin 18 (AN1) and pin 17 (AN0).

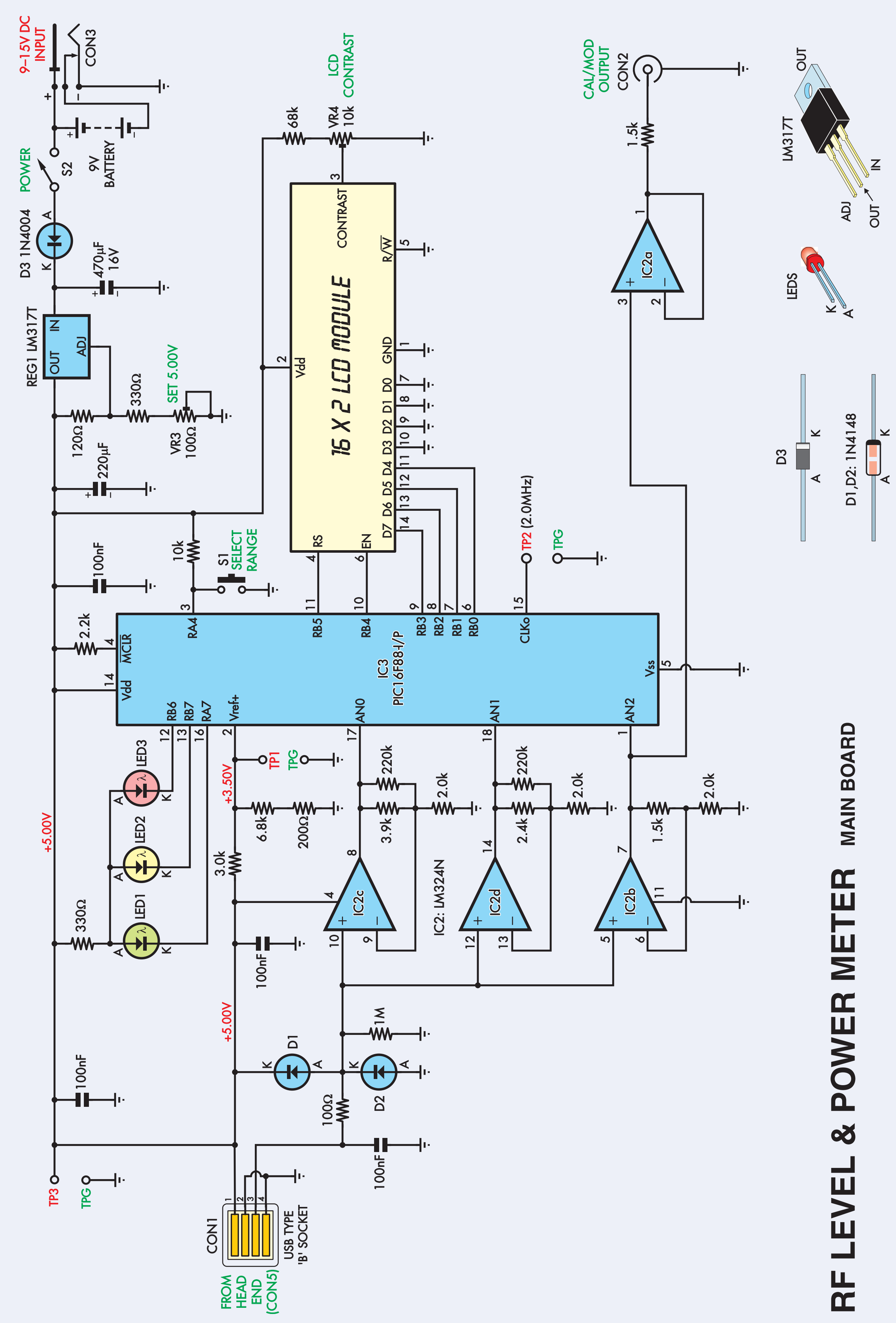
Why do we need three ranges? Because it allows us to get higher measuring resolution when the RF input signals (and hence the output voltage from IC1) are quite small. For these signals, we are able to amplify the DC output voltage from IC1, in order to use a larger proportion of the ADC's measurement range of 0V to 3.5V and hence increase the measurement resolution.

Gain ranging

We provide the three ranges in the following way. The incoming DC voltage from IC1 enters via pin 3 of CON1, and is then passed through a simple input protection circuit using diodes D1 and D2, the 100nF capacitor and the 100Ω and 1MΩ resistors. It is then fed to the paralleled inputs of op amps IC2b, IC2c and IC2d. Each of these provides a different amount of gain, to change the effective slope of the log-law input signal.

The gain for the normal default measuring range is 1.75, provided by IC2b with its 1.5kΩ and 2.0kΩ feedback resistors. This gives the incoming DC signal an effective slope of 1.75 × 20 or 35mV/dB, translating to a total span of 100dB for the ADC's 3.5V measuring range.

For signals of less than 223.9mV (–13dBV), we select the output from IC2d, configured for a gain of 2.19. This gives the incoming DC signal an effective slope of 43.74mV/dB, translating to a total ADC measuring span of 80dB. Then for signals of less than 22.39mV (–33dBV) we select the output of IC2c, with a gain of 2.916. This gives the incoming DC signal a slope of 58.32mV/dB, which translates to a total span of 60dB.



RF LEVEL & POWER METER MAIN BOARD

Fig.3: the main board circuit is based on an LM324 quad op amp (IC2) and a PIC16F88 microcontroller (IC3). The incoming signal is fed to paralleled op amp stages IC2b to IC2d, each operating with a different gain to provide three ranges. Their outputs in turn drive the ADC inputs of IC3, which processes the signals and drives a 16 × 2 LCD module.

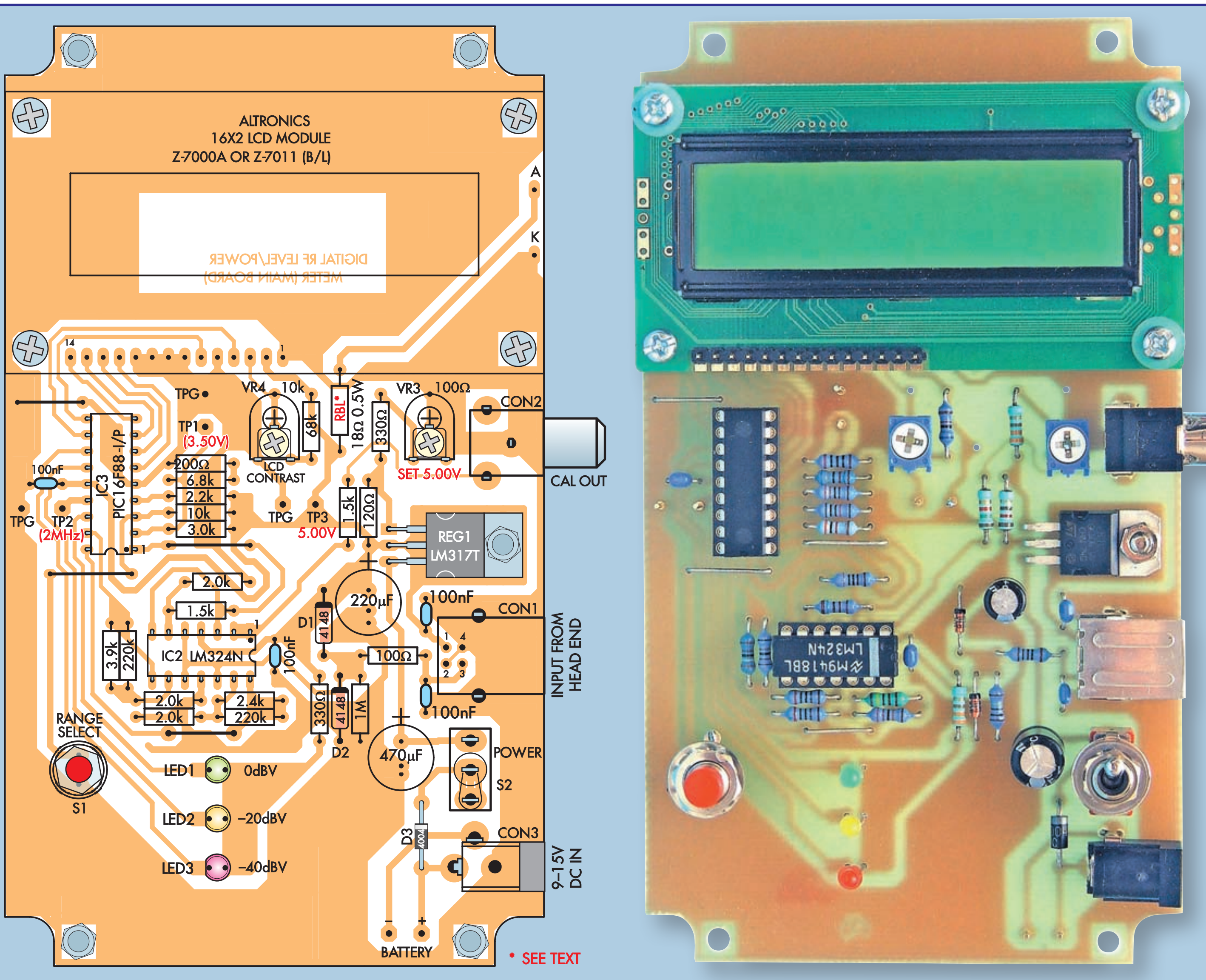


Fig.4: follow this parts layout diagram and the accompanying photograph to build the main board. Both IC2 and the PIC16F88 microcontroller (IC3) should be installed in sockets.

Using this approach we obtain much better measuring resolution for these much smaller signals. The outputs from op amps IC2c, IC2d and IC2b are fed directly to the AN0, AN1 and AN2 (ADC) inputs of the PIC and its firmware selects the appropriate ADC input channel by stepping from one range to the next each time you press the range select button (S1).

To indicate which range is currently selected, the firmware switches on LED1, LED2 or LED3 and automatically changes the scaling factor, so that the displayed values are correct. After performing the calculations for each measurement, the firmware then displays the results via the LCD module.

Power supply

The complete circuit runs from 5V DC, which is derived from either a 9V battery or a plugpack supply of similar voltage, using regulator REG1, an LM317T adjustable device. We use this rather than a fixed regulator because this allows us to set the supply rail accurately to 5.00V.

We need to do this because the 3.50V reference voltage for the PIC's ADC is derived directly from the 5V rail, via a voltage divider using 3.0kΩ, 6.8kΩ and 200Ω resistors. This reference voltage for the ADC is fed into pin 2 of the PIC, which is configured as the Vref+ input.

Notice that there are a number of test points provided in the main board circuit, to allow more convenient set-up and calibration. Test point TP1 allows you to measure the ADC reference voltage, so you can adjust trimpot VR3 to achieve exactly 3.50V at pin 2 of the PIC. TP3 also allows you to measure the 5.00V rail directly, if you wish, while TP2 allows you to check the PIC's internal clock oscillator.

This runs at 8MHz, which means that the signal available at TP2 should be very close to 2MHz (Fc/4). So, if the PIC is running correctly, you will find a 2MHz square-wave of 5V peak-to-peak at TP2.

Finally, the fourth op amp, IC2a, is provided purely as a voltage follower/buffer from the output of IC2b (the default ADC driver). Its output is made available via CON2, to allow you to monitor the amplified

output voltage from the AD8307AN head-end externally, with a DMM or oscilloscope.

This could be convenient for calibration and also for looking at any amplitude modulation of the RF signals being measured. Note that any observed modulation envelope is likely to be distorted because of the logarithmic response of the head-end amplifier.

Construction

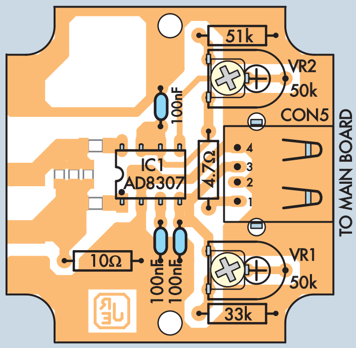
As noted earlier, the project is comprised of two parts: the AD8307AN head-end fitted into a small metal box for shielding and the main meter circuitry which is fitted into a UB1-size plastic box (158mm × 95mm × 53mm). The two are connected together using a standard USB interconnect cable.

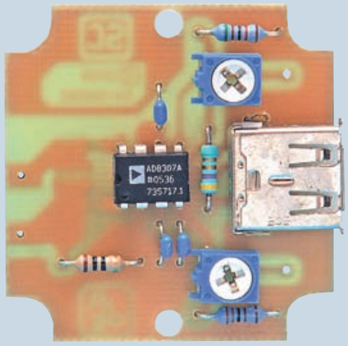
The meter's main circuit is all fitted on a PC board coded 783 measuring 146mm × 84mm, and with a recess in each corner so that it fits neatly behind the lid of the UB1 box. The head-end circuit is installed on a second PC board coded 784 and measures 43mm × 44mm. These boards are available, together with an attenuator PCB, as a set from the *EPE PCB Service*.

There is actually a third optional PC board for this project, coded 785 and measuring 95mm × 38mm. This is for an optional 20dB/50Ω attenuator, to allow measurements of higher-level signals.

The location and orientation of all parts mounted on the main board are shown clearly in the board overlay diagram of Fig.4. Note that connectors CON1, CON2 and CON3 are all mounted directly on the board, along the right-hand side. Power switch S2 also mounts directly on the board, with its connection lugs passing through the board and soldered to pads underneath.

Range select switch S1 can be mounted in the same way, or mounted on the box lid with its leads extended through the board using short lengths of tinned copper wire. The three range indicator LEDs are again mounted directly on the board, with the underside of their bodies spaced up by about 14mm so that the LEDs just protrude through the matching holes in the front panel (ie, the lid) when the board is mounted behind it.





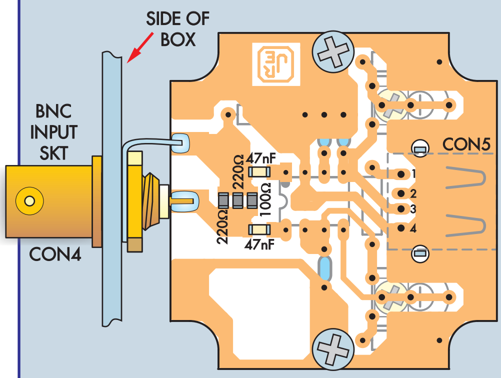


Fig.5: these two diagrams and the above photo show the parts layout on the head-end board. Use a fine-tipped soldering iron to solder the SMDs to the copper side of the PC board and take care to ensure that IC1 is correctly orientated. Do not use a socket for ICs – it must be soldered directly to the PC board.

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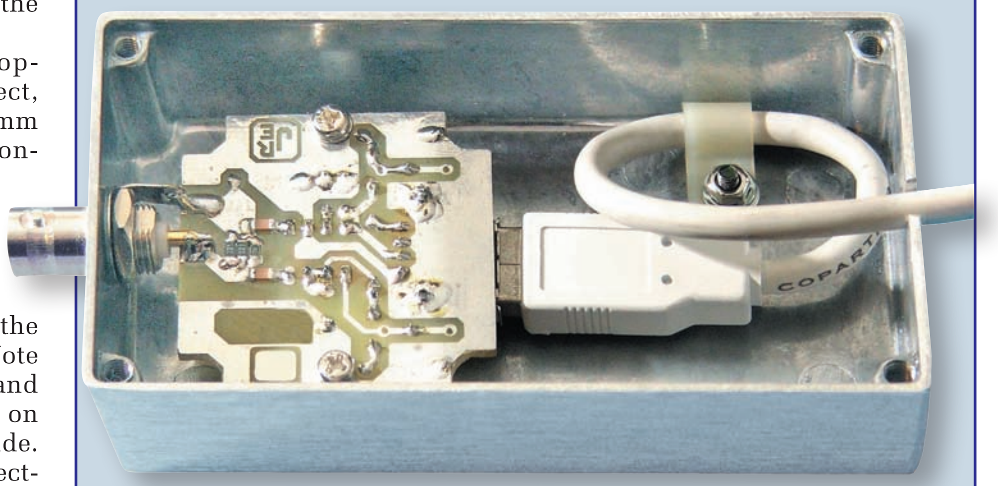


The head-end board is attached to a panel-mount BNC socket and mounted upside down inside a diecast metal case. A type A to type B USB cable connects the unit to the main PC board.

You should use sockets for IC2 and IC3, rather than soldering them directly to the board.

There are four wire links on the board and it's a good idea to fit these before any of the components so that they're not forgotten. The test point terminal pins can also be fitted at this stage, along with the two further pins used for the optional battery connections. By the way, these last two pins are mounted from the rear, to make the battery connections easier.

Mounting the LCD module

The LCD module used for this project is the Altronics Z-7000A or Z-7011, with the second type number signifying the version with a backlight. Regardless of which version you use, the module is mounted above the main board using four M3 × 15mm machine

What The Firmware Does

AS we explain in the main text, the AD8307 chip in the RF Meter's 'head end' detects the incoming RF signals and converts them into a DC voltage according to a logarithmic conversion scale. A PIC micro then measures and converts this into the equivalent RF voltage and power readings, under the control of a firmware program.

To do this, it makes use of a suite of maths routines made available to PIC programmers by Microchip Technology Inc, the manufacturers of the PIC family of micros. These routines are used to perform 24-bit and 32-bit floating-point addition, subtraction, multiplication and division, base-10 exponentiation, fixed-point multiplication and division, and floating-point to ASCII conversion.

Without going into much detail, the PIC firmware program works through the following sequence in making each measurement:

First it directs the PIC's 10-bit analogue-to-digital converter module to take a measurement of the DC output voltage from the AD8307 chip. It then converts that into 24-bit floating-point form, after which it is multiplied with a pre-calculated scaling factor (24-bit also) for the currently chosen measurement range. The resulting product is then divided by the ADC's full-scale value of 3FF (in 24-bit FP form), to give the measurement value in what I call the 'raw dB' form. This is essentially a 24-bit number varying between 0 and 100.

This raw dB value is then used to calculate the equivalent dBV value, by subtracting decimal 93 (in 24-bit FP form) and also the equivalent dBm value (for 50Ω impedance level) by subtracting decimal 80 (again in 24-bit form). These values are then saved for display, but also used to calculate the actual voltage and power levels.

The dBV value is used to calculate the equivalent voltage by first dividing it by decimal 20 (in 24-bit FP form) and then raising decimal 10 to that power using EXP1024, the Microchip 24-bit floating-point base-10 exponentiation routine. This is equivalent to calculating the antilogarithm, so we end up with the equivalent voltage value in 24-bit FP form.

After saving this for display, the program then does the equivalent calculation for power, taking the dBm value and first dividing it by decimal 10 and then again raising decimal 10 to that power using EXP1024. This gives the equivalent power in milliwatts, which is again saved for display.

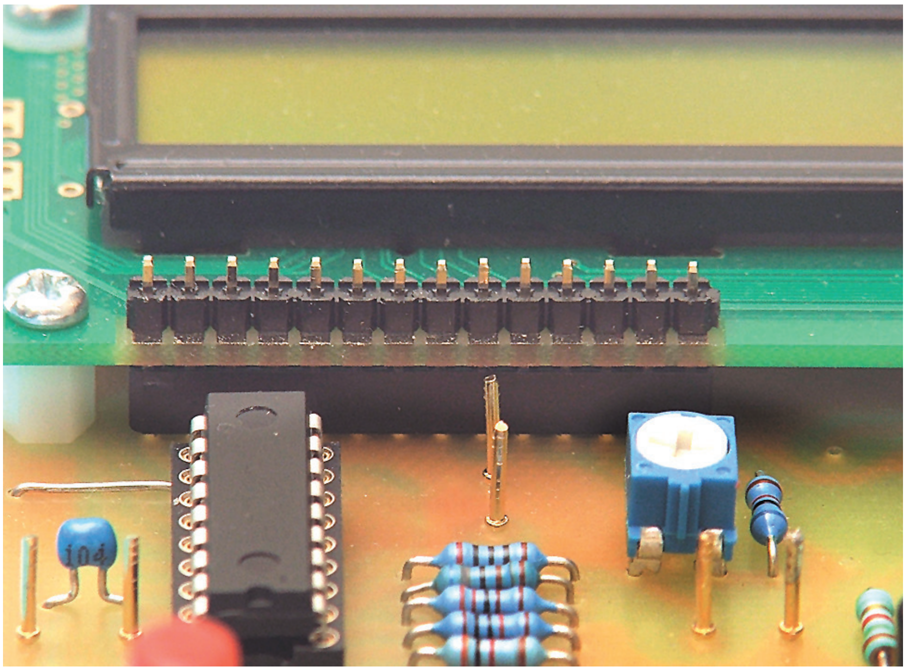
Once all four parameters have been calculated, the final steps of the measurement sequence involve taking each 24-bit parameter and processing it for display on the LCD module. For the dBV and dBm figures, this means working out the correct polarity indication (+ or –) and then using a Microchip routine called Float_ASCII to convert the numbers themselves into ASCII digits for display.

Things are a little more complicated for the voltage and power values, because these must first have their 24-bit binary exponents analysed to work out their scaling, the position of their decimal point and the most convenient multiplier to give them (eg, milli or micro).

After this is done, they are again converted into the equivalent ASCII digits using Float_ASCII.

As you can see, there's quite a bit of mathematical jiggery-pokery involved but luckily most of this is performed by Microchip's fancy maths routines.

The full source code for the firmware will be available on the *EPE* website, along with the source code for the floating point maths routines it uses (in a file called FPRF24.TXT) and, of course, the assembled hex code of the complete firmware ready to burn into a PIC.



This larger-than-life-size view shows how the LCD module is connected to the main PC board. A 14-pin header is soldered to the LCD module and this plugs into a matching 14-pin socket strip cut from a 28-pin IC socket.

screws, with M3 × 6mm tapped nylon spacers used as standoffs. Then nuts are fitted under the board to hold everything together **– but with one nylon flat washer under the nut at lower left,** to ensure that it doesn't short-circuit a PC board track close by.

The 14 main connections to these modules are all in a horizontal row at lower left. To make these connections reliably but in a manner which allows easy removal and replacement of the module if this is ever needed, we elected to use a custom-made 14-way plug and socket system.

The socket was made from one side of a 28-pin IC socket, cut away neatly and then mounted on the top of the main board. To mate with this socket, we made a plug from a 14-pin length of SIL pin strip, the pins of which were soldered to the pads on the underside of the module.

This must be done carefully, so that there is enough clean length of each pin extending down to mate

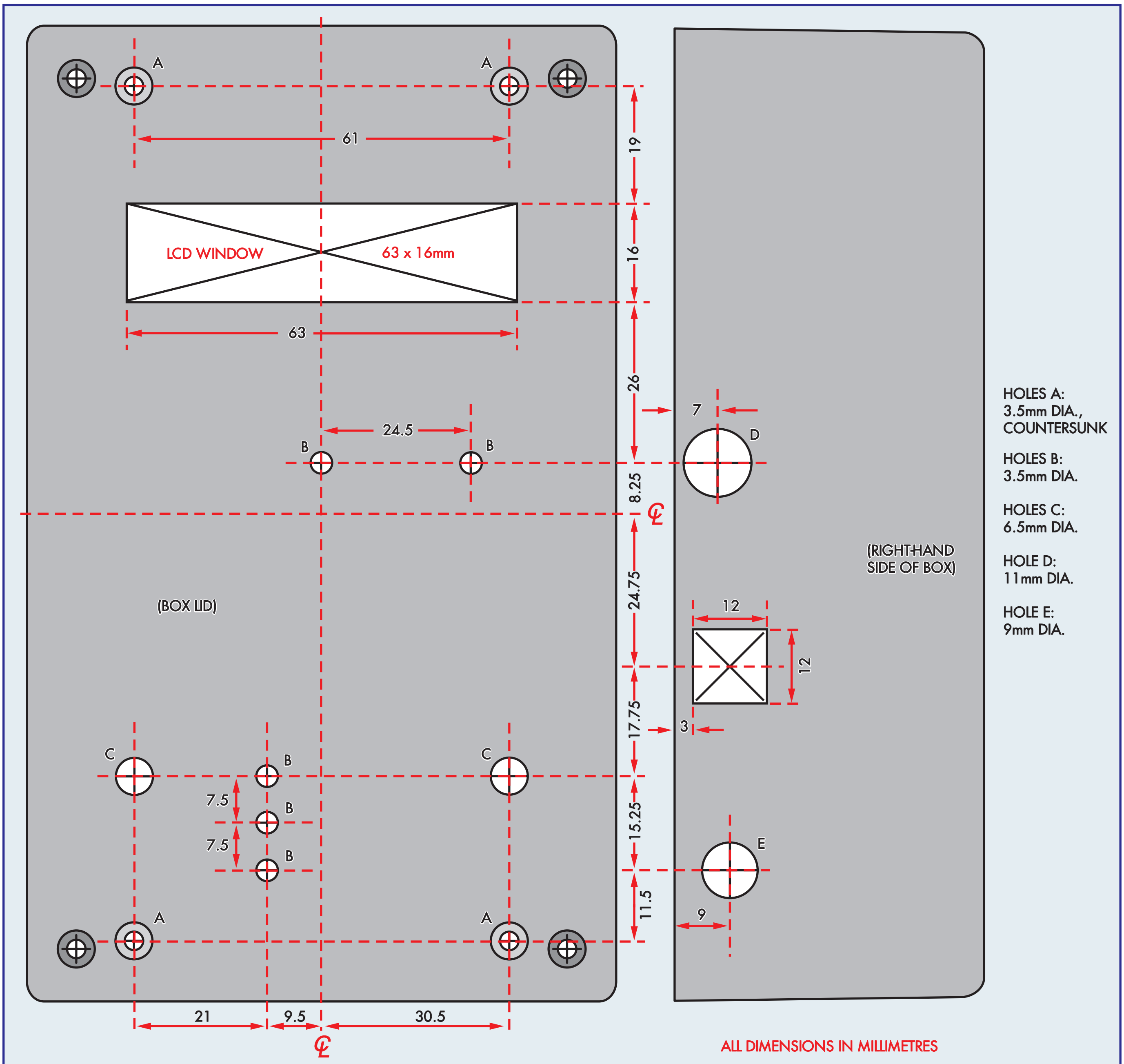


Fig.6: this full-size diagram shows the drilling details for the plastic case that's used to house the main PC board. The large cutouts can be made by drilling a series of holes around the inside perimeter, then knocking out the centre piece and filing the job to a smooth finish.

with the socket clips (easier to do than describe).

Backlit LCD module

If you use the backlit LCD module (Z-7011A) you will have to connect its 'A' and 'K' terminals (for the backlight LEDs) to the main PC board. This can be done using short lengths of tinned copper wire.

Similarly, resistor R_{BL} (18Ω 0.5W) is installed only if you are using this module. It gives a nominal LED current of about 80mA.

Once all of the components are mounted on the main board, it can be placed to one side while you assemble the head-end board.

Head-end board assembly

The board overlay diagrams for the head-end board are shown in Fig.5. The USB type A socket CON5 mounts on the top of the board, along with the two trimpots, four 0.25W resistors and three 100nF monolithic capacitors. **IC1 should be soldered directly into the board, to ensure an absolute minimum of input lead inductance.**

The remaining surface-mount components all mount on the copper side of this board, ie, the two 47nF input coupling capacitors and the three resistors used for the RF input termination. Solder these components carefully using a fine-tipped iron, using the 'tack first to hold it in position' technique to avoid damaging either the parts or the board pads.

When you have finished wiring up this board, place it aside also while you

Table 3: Resistor Colour Codes

❑	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❑	2	220kΩ	red red yellow brown	red red black orange brown
❑	1	68kΩ	blue grey orange brown	blue grey black red brown
❑	1	51kΩ	green brown orange brown	green brown black red brown
❑	1	33kΩ	orange orange orange brown	orange orange black red brown
❑	1	10kΩ	brown black orange brown	brown black black red brown
❑	1	6.8kΩ	blue grey red brown	blue grey black brown brown
❑	1	3.9kΩ	orange white red brown	orange white black brown brown
❑	1	3.0kΩ	orange black red brown	orange black black brown brown
❑	1	2.4kΩ	red yellow red brown	red yellow black brown brown
❑	1	2.2kΩ	red red red brown	red red black brown brown
❑	3	2.0kΩ	red black red brown	red black black brown brown
❑	2	1.5kΩ	brown green red brown	brown green black brown brown
❑	2	330Ω	orange orange brown brown	orange orange black black brown
❑	1	200Ω	red black brown brown	red black black black brown
❑	1	120Ω	brown red brown brown	brown red black black brown
❑	1	100Ω	brown black brown brown	brown black black black brown
❑	1	18Ω	brown grey black brown	brown grey black gold brown
❑	1	10Ω	brown black black brown	brown black black gold brown
❑	1	4.7Ω	yellow violet gold brown	yellow violet black silver brown

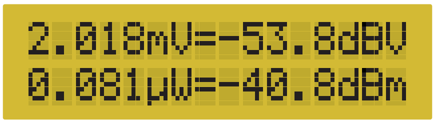


Fig.7: The display above shows typical level (top line) and power readings.

prepare the meter's two boxes by drilling and cutting the various holes in them. These are all shown in the drilling diagrams (Fig.6 and Fig.8), so the job should be quite straightforward.

To complete assembly of the head-end unit, first mount the BNC input connector CON4 in the hole at the end of the metal box, with the lug of its earthing washer oriented at '3 o'clock' so that once the mounting nut is fully tightened, it can be bent out at 90°, ready to be soldered to the PC board copper (along from the socket's centre spigot – see Fig.5). Then mount the head-end PC board upside down inside the upper part of the box, ie, with the trimpots underneath and facing the matching adjustment holes in the top of the box.

The board is mounted using two M3 × 10mm tapped nylon spacers as stand-offs, with M3 × 6mm countersink-head screws holding the spacers inside the box, and pan-head M3 × 6mm screws attaching the board assembly to them.

Once the board assembly is mounted in position, you can solder the centre spigot and earthing lug to their respective pads on the board to complete the input connections. The USB cable's

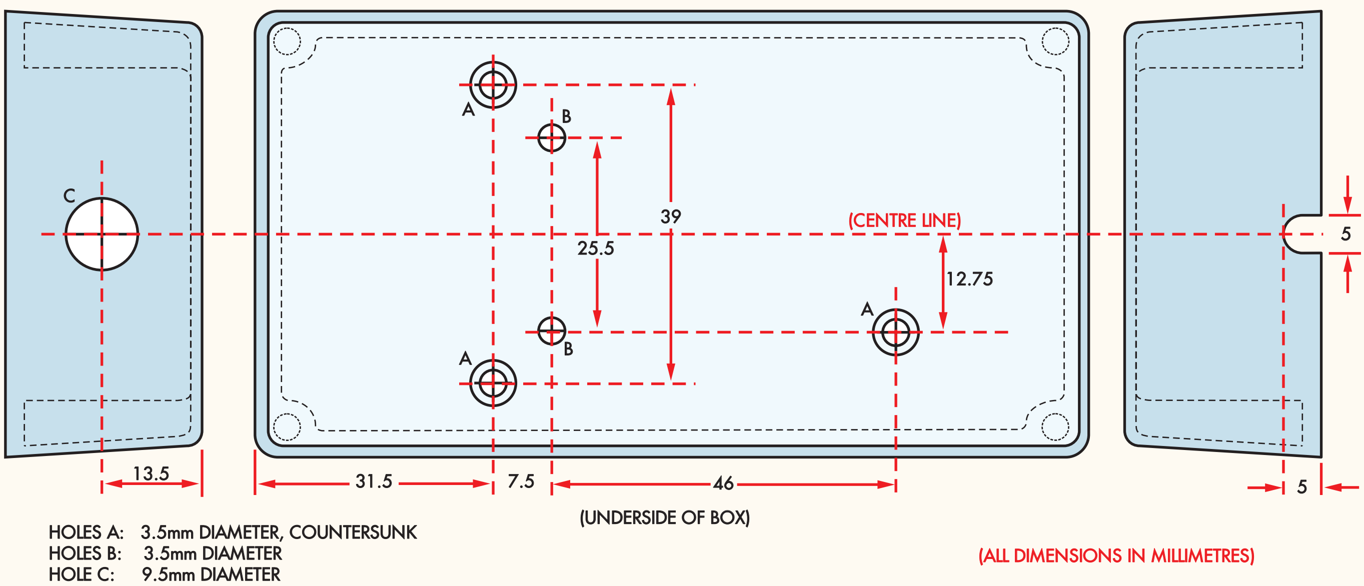


Fig.8: here are the drilling details for the diecast aluminium box that's used to house the head-end board assembly.

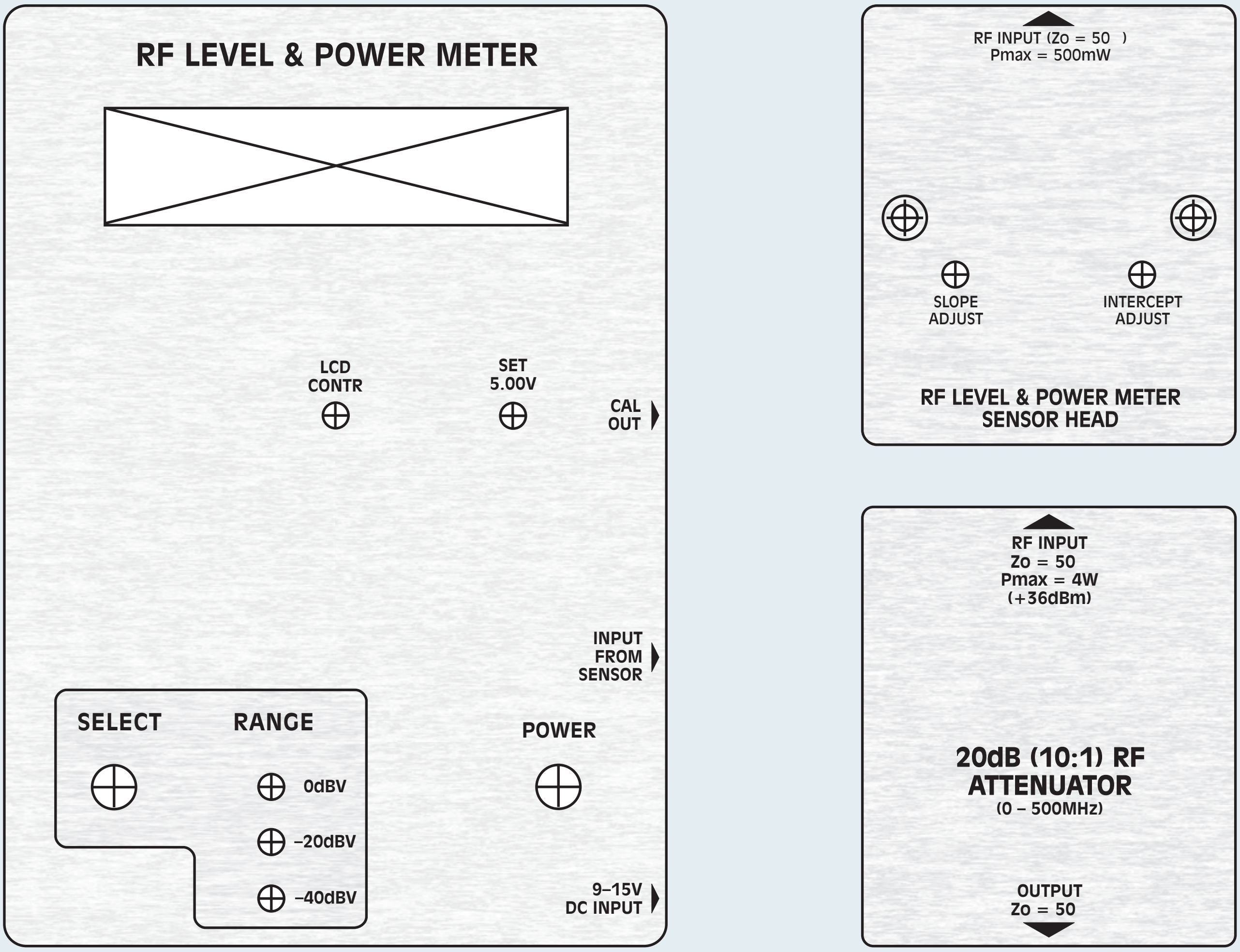
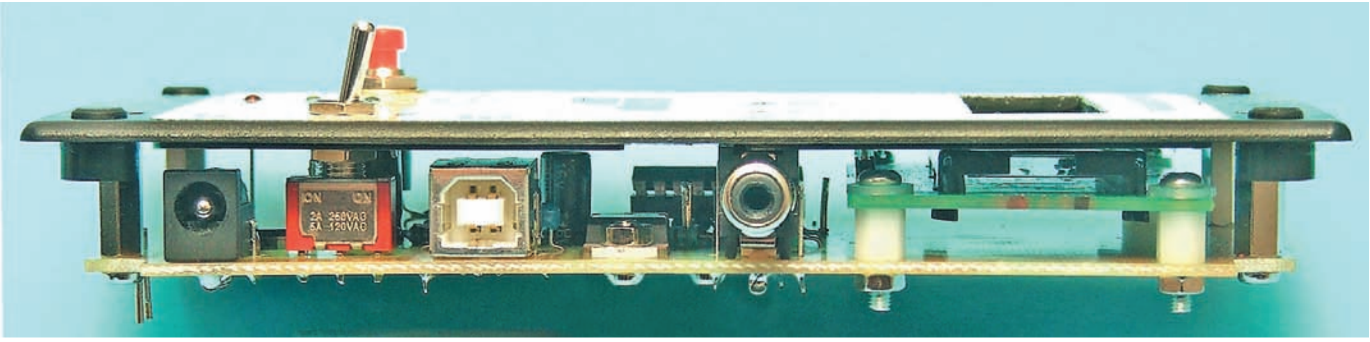
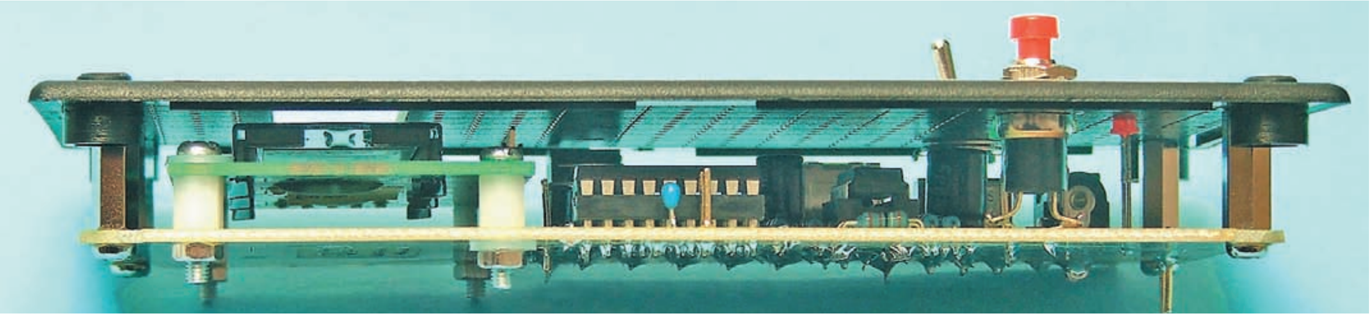


Fig.9: this full-size artwork can used to make the front panels of the various units, including the Sensor Head case and the optional RF Attenuator (see text).





The main PC board is attached to the lid of its case via four M3 × 15mm tapped spacers. Four M3 × 6mm countersink-head screws secure the lid to the spacers, while four M3 × 6mm pan head screws are used to secure the PC board.

Optional 20dB (10:1) RF Attenuator

YOU will have noticed from the specification panel that the maximum input level of the basic power meter is essentially +7.0dBV, corresponding to 2.238V, 100mW into 50Ω and +20dBm.

As this may be a little low for some applications, we have designed a compact 20dB (at 50Ω) wideband attenuator which may be used to extend the meter's range up to 22.38V (+27dBV) and +40dBm (10W) – although it may not be able to cope with 10W of input power for more than a few seconds if you have to use 0805-type SMD resistors.

SMD resistors are used because they have low parasitic inductance and capacitance. However, they also have fairly low power dissipation (especially the 0805 size). Try to use the larger 1206-size resistors if you can, especially in the input leg. Otherwise, the continuous input power rating will be limited to about 4W.

Despite this limitation, this attenuator can be built quite cheaply and would make a handy optional extra for the meter for those who want to be able to measure higher RF levels. Please note, however, that when the attenuator is connected ahead of the meter's head-end, the meter itself won't be able to allow for the extra 20dB of attenuation.

This means that you'll need to add 20dB to the readings yourself, although this shouldn't be too much of a chore.

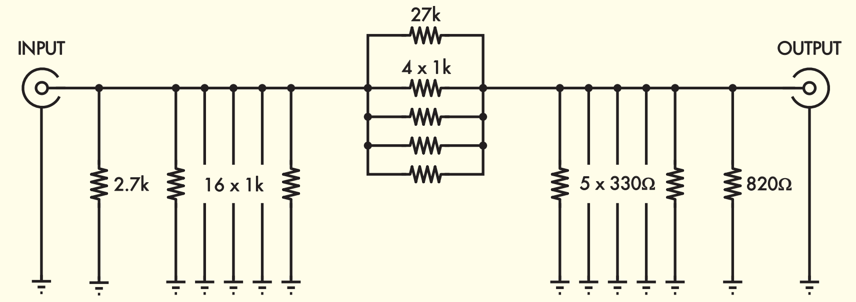


Fig.10: the circuit for the optional 20dB RF attenuator uses a standard pi-section configuration. The resistors are all surface mount types.

All you need to do is add 20dB to the dBV and dBm readings. You will have to multiply the voltage reading by 10 and multiply the power reading by 100.

Construction details

The circuit for the attenuator is shown in Fig.10 and it is a standard π-section (pi) type. Everything fits on a small PC board measuring 95mm × 38mm and coded 785 which fits in a second diecast aluminium box identical to that used for the head-end.

Fig.11 and the photos show the parts layout on the PC board.

Note that the board assembly is supported behind the box lid simply by soldering the input and output pads to the 'active' spigots of the BNC connectors. Multiple short pieces of tinned copper wire (resistor lead offcuts) are used to make the connections from the earthing lug of each socket to the earthy side of the board copper.

Shield plate

As you can see from the internal photos, the prototype attenuator has a small shield plate which was mounted vertically across the centre of the attenuator, to reduce the possibility of RF energy radiating past the attenuator pad at the highest frequencies. This is probably 'gilding the lily', but you may want to add such a shield to your attenuator also. It can be cut from a small rectangle of blank PC board and is supported by soldering it to four PC board terminal pins fitted to the earth copper at the centre of the main board.

type-A plug can then be mated with socket CON5 at the other end of the board, after which the cable can be fitted with its P-type clamp, which is then fastened into the box using an M3 × 10mm countersink-head machine screw with a nut and lockwasher. The cable is then looped around and fed out of the box via a rounded slot cut in the end and the box lid screwed on to complete the assembly.

Initial checkout

At this stage, you should be ready to give your RF Level and Power Meter a preliminary functional checkout, because this is easiest done before the main board is attached to the lid/front panel of the main box. Don't worry if S1 (the range select button) hasn't been mounted on the main board at this stage – it's not really necessary for this operation.

To begin, make sure that IC2 and IC3 have both been plugged into their sockets the correct way around and then set trimpots VR3 and VR4 to the centre of their ranges. After this, connect the main board to a suitable source of 9V DC, either via a battery connected to the pins at the bottom of the board or a plugpack lead plugged into CON3. There's no need to plug in the lead from the head-end as yet.

When you apply power via switch S2, LED1 should light and you should be greeted by a reassuring glow from LED1 and 'RF Level/Pwr Meter' on the LCD, although you may have to adjust trimpot VR4 before this message is displayed clearly and with good sharpness. Note that this message only lasts for a few seconds, after which it is replaced by the meter's normal display of readings.

If all is well so far, you can now set the Vref+ voltage at pin 2 of IC3 to 3.50V. This is done with one adjustment. Connect your DMM to TP1 and its nearby TPG pin and then adjust

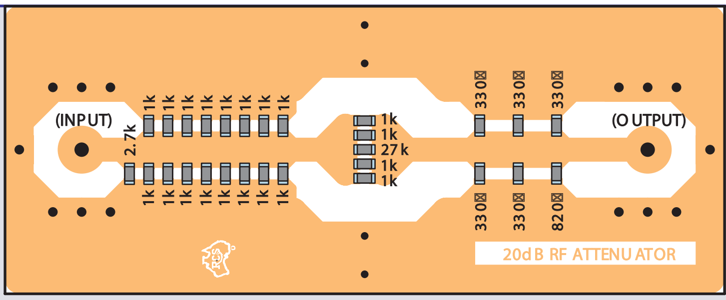
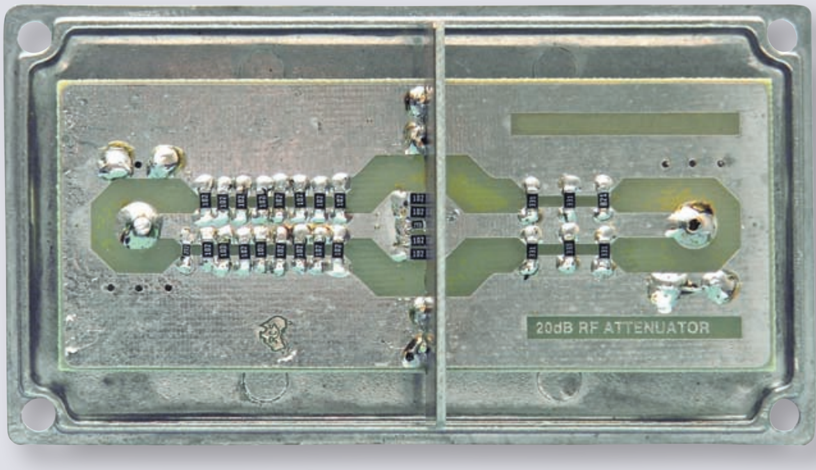
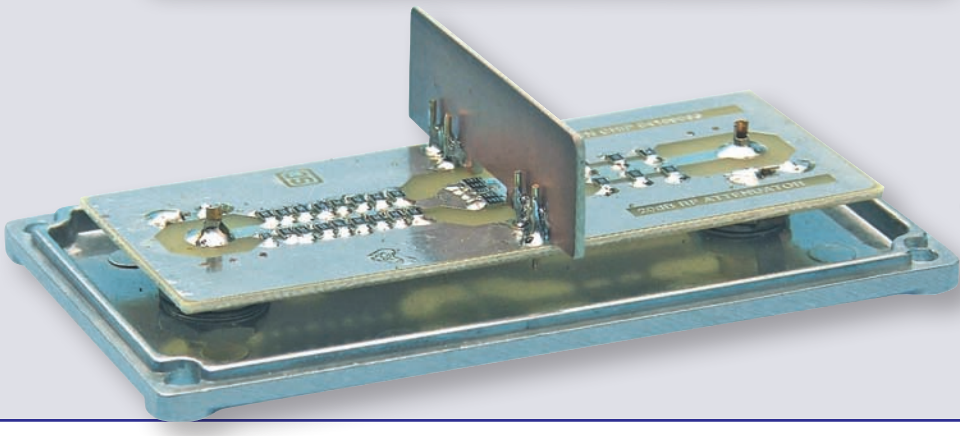


Fig.11: follow this diagram to build the RF Attenuator board. The copper side of the board carries the SMD resistors, plus four PC stakes to support the central shield plate (see photos below). The BNC input and output sockets are mounted on the other side of the board.



Above: because RF signals are involved, the RF Attenuator must also be housed in a metal diecast case.



Left: the RF Attenuator board is secured to the lid of the case via the BNC input and output sockets. Note how the central shield plate (consisting of blank PC board material) is supported by soldering it to four PC pins in the centre of the attenuator's PC board.

trimpot VR3 until you get a reading as close as possible to 3.50V. This should also set REG1's output to close to 5V.

Use your most accurate DMM when making this adjustment, because to a large extent, the accuracy of this setting will determine the accuracy of your RF Level Meter.

That completes the initial set-up, although if you have access to a 'scope or a frequency counter you may want to check the PIC's clock signal at TP2 and its TPG pin. You should find a 5V peak-to-peak square wave with a frequency very close to 2MHz.

Main box assembly

You are now ready to mount the main board assembly behind the lid of the main box (the lid becomes the front panel). It attaches to the lid via four M3 × 15mm tapped spacers which are fastened using M3 × 6mm countersink-head screws. The board is then attached to the spacers using four pan-head M3 × 6mm screws.

You will need to remove the upper mounting nut from switch S2 so that the threaded ferrule of S2 can pass up through its matching hole in the lid during this assembly. You also need to make sure that LEDs 1 to 3 are positioned so they pass up through their corresponding holes in the lid.

If you have elected to mount S1 on the lid before this assembly, you'll also need to ensure that its connection lugs or their extension wires pass down through their corresponding holes in the circuit board.

When this part of the assembly is complete, the top nut for S2 can be carefully refitted to the top of the switch ferrule and the lower nut and its lockwasher underneath carefully wound up to support the lid.

Your meter's main board assembly should now be complete and can be lowered into the box. This needs to be

Parts List – Digital RF Level & Power Meter

*1 PC board, code 783, size 146mm × 84mm
*1 PC board, code 784, size 43mm × 44mm
*Available as a set from the *EPE PCB Service*
1 UB1-size plastic box (158mm × 95mm × 53mm)
1 diecast aluminium box, size 111mm × 60mm × 30mm
1 16x2 LCD module, Altronics type Z-7000A or Z-7011A (with backlight illumination)
4 M3 × 6mm tapped Nylon spacers
4 M3 × 15mm machine screws
1 SPST pushbutton switch, momentary (S1)
1 SPDT mini toggle switch (S2)
1 USB type B socket, PC-mounting (CON1)
1 phono socket, PC-mounting (CON2)
1 2.5mm concentric DC socket, PC-mounting (CON3)
1 14-way SIL socket (half of 28-pin IC socket)
1 14-way length of SIL terminal strip
1 18-pin IC socket
1 14-pin IC socket
4 M3 × 15mm tapped metal spacers
4 M3 × 6mm countersunk machine screws
5 M3 × 6mm pan head machine screws
5 M3 nuts, with star lockwashers
1 M3 Nylon washer
8 1mm-diameter PC board pins
1 PC-mount type A USB socket, PC-mounting (CON5)
1 panel-mount BNC socket
2 10mm long M3 tapped Nylon spacers
2 6mm long M3 machine screws with lockwashers
2 6mm long M3 countersunk machine screws
1 USB cable, standard type A to type B
1 P-type 5mm plastic cable clamp
1 10mm long M3 countersunk machine screw
1 M3 nut, with flat and star lockwashers

Semiconductors
1 AD8307AN log detector/ amplifier (IC1)
1 LM324N quad op amp (IC2)
1 PIC16F88-I/P microcontroller programmed with firmware (IC3)
1 LM317T adjustable voltage regulator (REG1)
1 3mm green LED (LED1)
1 3mm orange/yellow LED (LED2)
1 3mm red LED (LED3)
2 1N4148 diodes (D1,D2)
1 1N4004 diode (D3)

Capacitors
1 470µF 16V radial electrolytic
1 220µF 10V radial electrolytic
7 100nF monolithic
2 47nF ceramic, 1206 SMD chip

Resistors (0.25W 1%)

1 1MΩ	3 2.0kΩ
2 220kΩ	2 1.5kΩ
1 68kΩ	2 330Ω
1 51kΩ	2 220Ω (0805 SMD)
1 33kΩ	1 200Ω
1 10kΩ	1 120Ω
1 6.8kΩ	1 100Ω
1 3.9kΩ	1 100Ω (0805 SMD)
1 3.0kΩ	1 18Ω 0.5W (RBL)
1 2.4kΩ	1 10Ω
1 2.2kΩ	1 4.7Ω

Trimpots
2 50kΩ mini horizontal trimpot (VR1,VR2)
1 100Ω mini horizontal trimpot (VR3)
1 10kΩ mini horizontal trimpot (VR4)

Optional 20dB attenuator
*1 PC board, code 785, size 95mm × 39mm
1 diecast aluminium box, size 111mm × 60mm × 30mm
2 BNC panel-mounting sockets
1 27kΩ resistor, 1206 or 0805 SMD chip
1 2.7kΩ resistor, 1206 or 0805 SMD chip
20 1kΩ resistor, 1206 or 0805 SMD chip
1 820Ω resistor, 1206 or 0805 SMD chip
5 330Ω resistor, 1206 or 0805 SMD chip
4 1mm-diameter PC pins

done with the right-hand side angled downwards, so that the outer sleeve of phono connector CON2 slips into its hole in the side of the box, allowing the lid assembly to be swung down as well. The self-tapping screws supplied can then be used to fasten the lid assembly inside the box.

Final adjustment

Now we come to adjustment and calibration. To do this, you'll need an RF signal generator which is able to supply an RF signal (preferably unmodulated) of known level.

If you don't have access to such a calibrated generator, an alternative is to use an uncalibrated RF oscillator with another RF measuring instrument of some kind to let you adjust its output to a convenient level – such as 1.0V RMS.

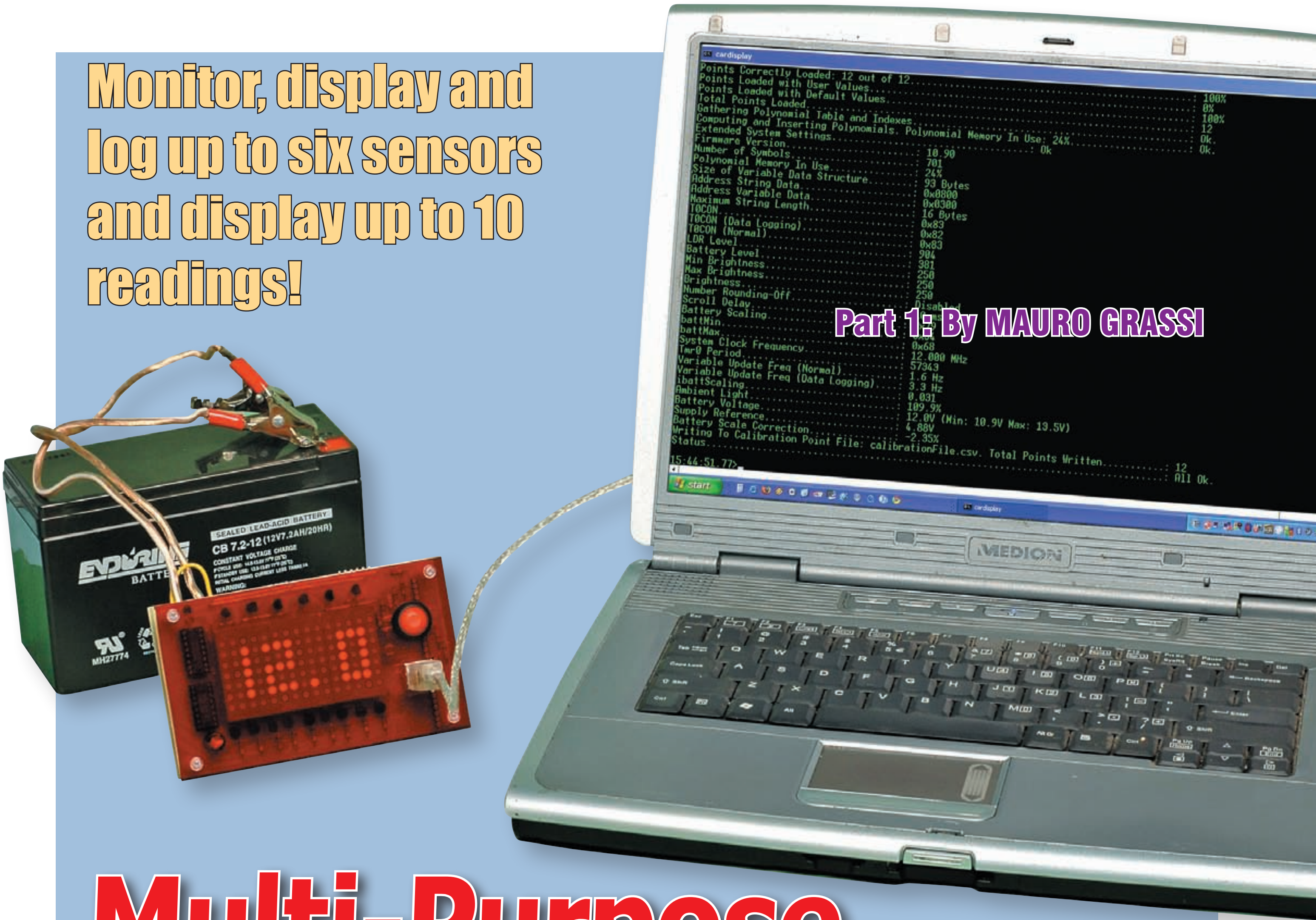
The calibration process is quite simple. First, plug the cable from the head-end into CON1 on the main board, then fit a 50Ω termination load plug to the RF input of the head-end so that it has a nominal RF input of 'zero'. Now turn on the meter's power switch (S2) and check the LCD readout after the greeting message has been replaced by the normal readings.

Pay particular attention to the dBV reading, because initially you'll probably find that it shows a figure rather higher than it should. After leaving it for a few minutes for the circuit to stabilise, try adjusting the 'Intercept Adjust' trimpot (VR2) on the head-end board carefully with a small screwdriver or alignment tool, to reduce the reading down to the lowest figure you can – ideally below –80dBV.

The next step is to remove the 50Ω termination plug from CON4 and instead connect a cable from the output of your RF generator. Set the generator to some convenient frequency (say 100MHz) and of course with a known RF level – say 1V (0dBV). It's then a matter of adjusting the 'Slope Adjust' trimpot (VR1) on the head-end unit – again with a small screwdriver – until you get a reading of +00.0dBV on the LCD. Once that's done, your RF Level and Power Meter is finished, set-up and ready for use.

Finally, note that you will have to power this device from a plugpack if you use the backlit LCD, as the current is too high for battery power. *EPE*

Monitor, display and log up to six sensors and display up to 10 readings!



Part 1: By MAURO GRASSI

Multi-Purpose Car Scrolling Display

This project started out as a digital dashboard display, but has grown and can be used in any measurement or data logging application where you have 9V to 12V DC available. It can monitor up to six signals and display up to 10 computed values in a scrolling or static readout on a 7 × 15 dot matrix LED display.

SO WHAT'S a scrolling display? You really need a short video to show what this project does. The readout continually 'scrolls' from left to right, displaying one, two and up to 10 computed values from up to six different signals. Each value is preceded by its description, such as battery voltage, temperature, duty cycle and so on. If you want to focus on one reading, pressing the sole pushbutton will make the display static.

Anyway, let's just give a sample of what this project can do:

- **Measure engine temperature** – have a relay switch on above a user preset temperature.
- **Measure fuel injector duty** – have a relay switch if the duty cycle is too high or too low.
- **Measure engine RPM** – have a relay

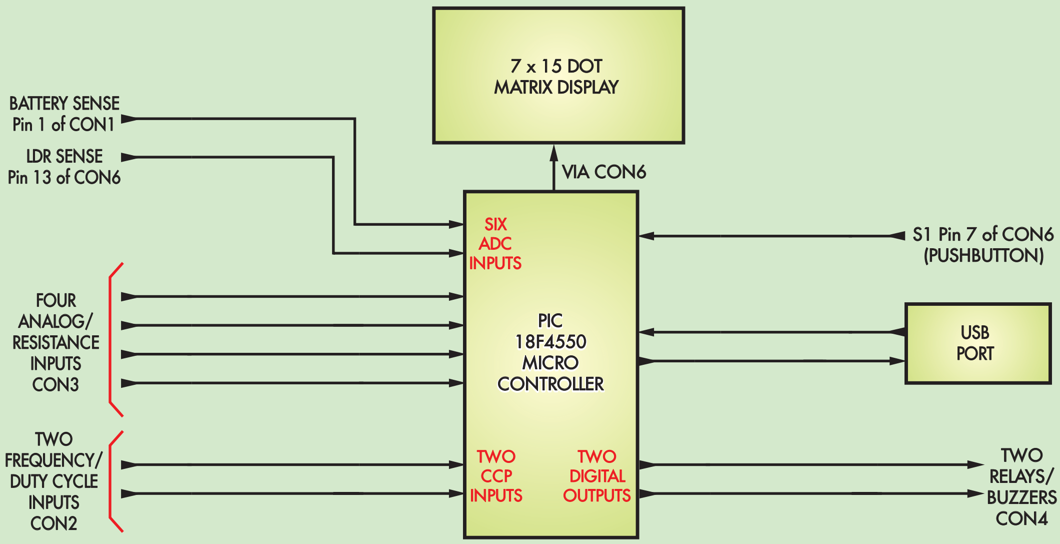


Fig.1: block diagram of the Car Scrolling Display. A PIC 18F4550 microcontroller is at the heart of the project. It processes various inputs, drives the dot matrix display, manages the USB connection and drives the two outputs.

switch on at a preset RPM (perhaps to indicate when to change gear).

- **Measure throttle position and delta throttle position** – if the accelerator pedal is pressed too abruptly, a relay can be made to switch on this condition.
- **Measure speed** – have a relay switch if the speed is too high or too low.
- **Measure fuel tank level** as a percentage of full tank – have a relay switch on or off if the level is too high or too low.
- **Measure battery voltage** – have a relay switch on if the voltage is too high or too low.
- **Measure air/fuel ratio** – have a relay switch on if the mixture is too rich or too lean.
- **Measure cabin temperature** – switch on a fan via a relay if it is too high.
- **Measure almost any signal** coming from the ECU.

So pick any six of the above possibilities and that is what this project could do in your car. But that is just for applications involving cars. In reality, this project can be used anywhere where a 9V to 12V DC supply is available, or you have a computer with a USB port. It accepts voltage, resistance, frequency or duty cycle inputs, and has two digital outputs for switching on limit conditions. We're sure you can think up lots more potential applications.

The project uses two PC boards stacked with red perspex on top. The top (display) board has a group of three 7 × 5 dot matrix displays, a USB port and a single pushbutton. The main (lower) PC board has the microcontroller and all the supporting circuitry for the connections and the optional output connections to relays or buzzers.

To build and set it up, you will need a laptop or desktop computer with a spare USB port. You will use Windows-based software (downloadable from **www.epemag.com**) to set the measurement functions, calibrate the sensors and do data logging.

The LED display can be dimmed (either automatically by sensing the ambient light level, or manually) and you can select the scrolling speed of the display, as well as the names of the measurements and their units. In static mode, the LED readout can display up to four digits. It can also be turned off using the front panel pushbutton.

Outputs

The two output channels can drive external 12V relays directly and can be programmed to respond to maximum and minimum settings for any of the measured variables. Alternatively, the outputs could drive buzzers to give an audible indication that signals have exceeded their programmed limits.

You can choose different sounding buzzers to indicate maximum or minimum conditions, when using two different buzzers. Or you can use only one buzzer and the maximum and minimum limits are indicated by different sequences of beeps.

When you only need a visible indication of a limit condition, there are visible cues (a flashing display for a minimum condition and an inverted display for a maximum condition) on the LED display when in static mode.

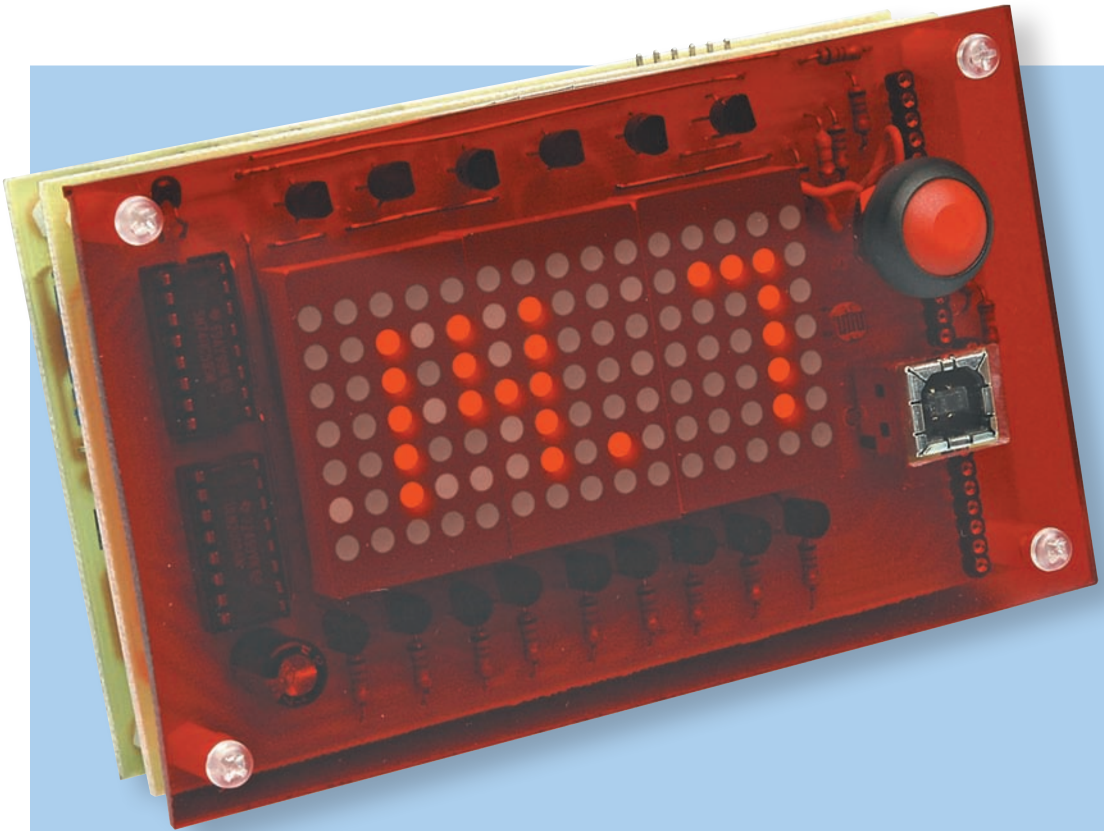
So there are many uses for this display, and it's really up to you as to how you set it up.

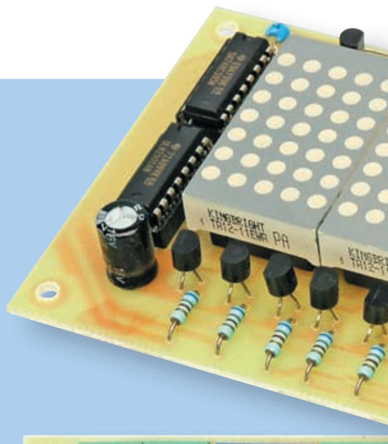
User operation

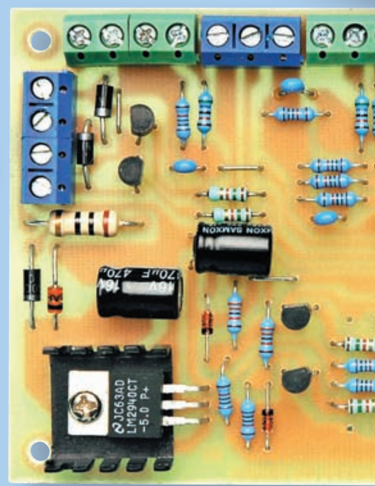
User operation of the Car Scrolling Display has been kept deliberately simple. There is just one pushbutton on the front panel (S1), a momentary SPST switch. The firmware recognises a short press and a long press. A short press is anything less than about a second, while a long press is anything more than that.

There are three display modes. You switch to the next display mode by holding S1 pressed for more than a second, ie, by making a long press.

The first is the **Scrolling Mode** where only the selected reading is continuously displayed as a scrolling string. In this mode, pressing S1 for less than a second (ie, a short press) will take you to the next reading, and that will then scroll continuously. After you have scrolled to the last reading, making a short press will turn the display off. The sequence can then be repeated.







The unit is built on two PC boards – a main board and a display board. These are stacked together, along with a red perspex panel for the dot matrix displays (assembly details next month). Note that the boards shown are prototypes and the final versions are slightly different.

The second display mode is the **Static Mode**. In this mode, the selected reading is displayed without scrolling. You can make a short press to go to the next reading. Again, making a short press after the last reading turns the display off. The sequence then repeats again.

The third and last display mode is the **All Scrolling Mode**. In this mode, all readings are displayed as a scrolling string. The string then repeats continuously. Pressing S1 while in this mode takes you to the first display mode again and the whole sequence repeats from there.

In both scrolling modes, the name of the variable, the value and the unit are displayed as a scrolling string. In **Static Mode**, up to four digits are displayed at once.

In **Static Mode**, a maximum condition is indicated by the display flashing every second or so between normal and reverse modes, ie, all the normally lit dots become unlit, and vice versa – Fig.5. This is a very dramatic mode to indicate a problem condition. A minimum condition, on the other hand, is indicated by a flashing reading. As indicated, these visual cues are only available in Static Mode.

Note that the **Battery Voltage** is always displayed first. For each of the displayed variables, you select the variable number and the value index to display. You also set the order in which they are displayed.

Remember that you can change all settings and perform the required calibration using a laptop and a USB cable.

Electrical signals in cars

All modern cars have an ECU (Electronic Control Unit) that manages the ignition timing and fuel injection. Almost all electrical sensors in your car produce a voltage or vary their DC resistance, depending on the quantity being measured, or produce a digital signal (varying the frequency or duty cycle) to indicate the reading.

Different sensors have different voltage ranges. For example, a narrowband air/fuel sensor may have an output in the 0V to 1V range, whereas a tachometer sensor output may be a square wave at 5V, with the frequency of the signal proportional to the engine's RPM.

By contrast, a fuel injector signal is digital (12V amplitude), with the positive period (ie, the time the signal is at a high level) normally proportional to the time the injectors are firing. Alternatively, it may be inverted, with the negative period indicating the firing of the injectors. Since all calibration is done in software, either negative or positive duty cycles can be monitored.

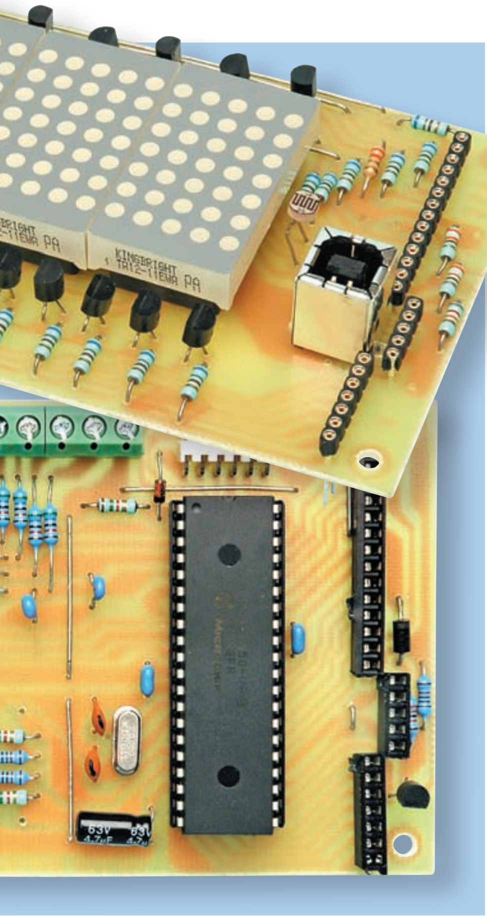
This project will accept all of these types of signals and with software calibration via the USB port, it is easy to adapt to a wide range of different sensors.

How it works

The block diagram of Fig.1 shows the main features of the circuit. As you can see, a microcontroller is the heart of the project and it drives the dot matrix displays, manages the USB connection and drives the two outputs.

Fig.3 shows the circuit of the main board, while Fig.4 shows the circuitry of the display board. In Fig.3, IC1 is the PIC18F4550 microcontroller and there are four multi-way terminal blocks.

CON1 (4-way) provides the connections to the battery or DC supply. The 12V input from the car's battery is passed through a 10Ω 1W resistor



and a reverse polarity protection diode (D1). The 10Ω resistor will normally drop around 2V because the circuit typically draws around 200mA, depending on the display brightness and the number of lit pixels.

A 16V Zener diode (ZD1) clamps the input voltage in case of transients. This is necessary to protect both the input supply bypass capacitor (470µF, 25V) and the 3-terminal low-dropout regulator REG1 (a LM2940-5).

The entire circuit runs from the +5V rail output from REG1. This supply rail is bypassed by a 47µF 16V capacitor and the 100nF monolithic capacitors near the microcontroller and the other logic ICs.

CON2 (4-way) accepts the two identical frequency/duty cycle inputs. Considering pin 2 of CON2, for example, the signal is applied to the base (B) of a BC337 transistor (Q19) through a 33kΩ resistor. The 10kΩ resistor to ground sets the switching threshold to around +2.6V. That is, the transistor switches on when the signal input is above +2.6V and switches off for voltages below that.

Diode D5 clips any negative voltage excursions of the signal to the base of the transistor to around –0.6V.

The collector (C) output of the transistor is pulled up by a 10kΩ resistor and is fed to the CCP1 (Capture/Compare) input (pin 17) of IC1 via a low-pass filter composed of a 1kΩ resistor and a 10nF capacitor. This low-pass filter removes potentially noisy signal transitions.

Frequency and duty cycle

The frequency and duty cycle of the input signal is measured by capturing the value of an internal timer run from the microcontroller's system clock (12MHz). It counts how many system clock ticks occur when the signal is low and when the signal is high.

The counter is 24 bits wide. For example, when applying a 40% duty cycle rectangular wave at 100Hz, we will obtain the following counter values:

C_{High} = 48,000 and C_{Low} = 72,000

In other words, the internal timer running from 12MHz signal counts up to 48,000 in the time that the signal is high and up to 72,000 in the time the signal is low.

From these two values, the firmware calculates the frequency and duty cycle as follows:

$$\text{Freq} = 12{,}000{,}000/(C_{High} + C_{Low})$$

and:

$$\text{Positive Duty Cycle} = 100C_{High}/(C_{High} + C_{Low})$$

Voltage/resistance inputs

The four voltage/resistance inputs are connected to the 6-way connector CON3.

Each analogue input passes through a voltage divider consisting of 22kΩ and 10kΩ resistors and bypassed by a 100nF capacitor. Each resulting voltage is then digitised by the microcontroller using the onboard ADC (analogue-to-digital converter) which has 10 bits of resolution and whose full range is from 0V to 5V.

The division factor from the 22kΩ and 10kΩ resistors is 3.2, which means that the analogue inputs have a full range of 0V to 16V, suitable for most applications in a car or any vehicle with a 12V battery.

Any voltages above 16V will not be correctly read (ie, readings will plateau), because the input protection diodes on the ADC inputs of IC1 will begin to conduct. The high series input impedance will ensure that the input itself is not damaged.

The downside of having a large dividing factor of 3.2 (16V = 5V ×

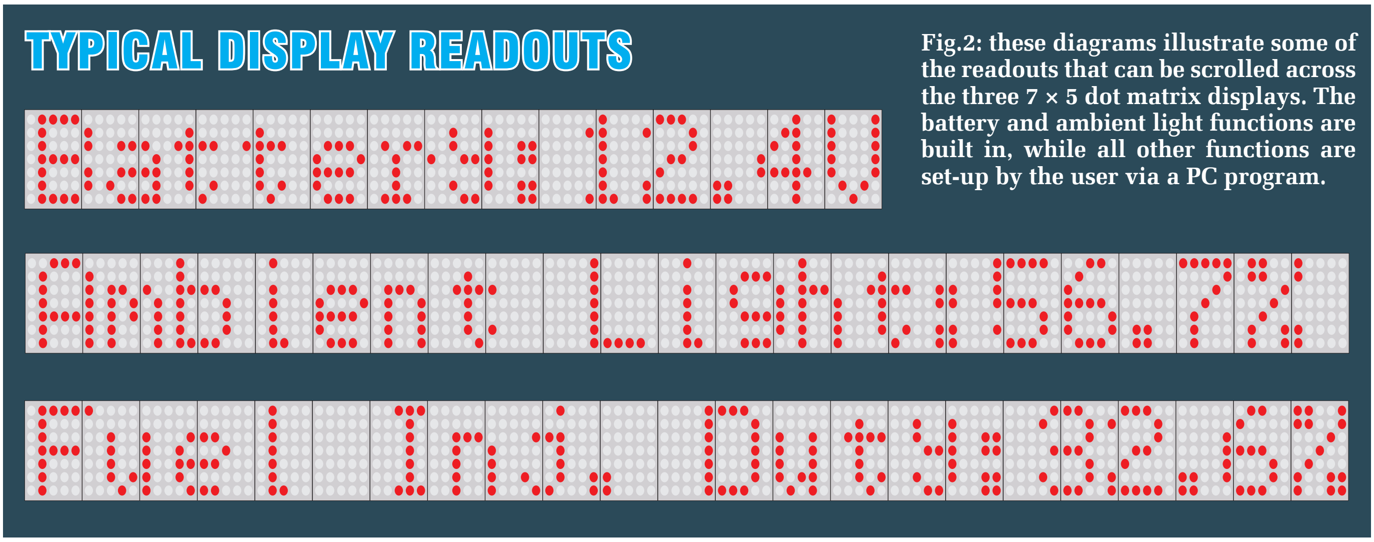
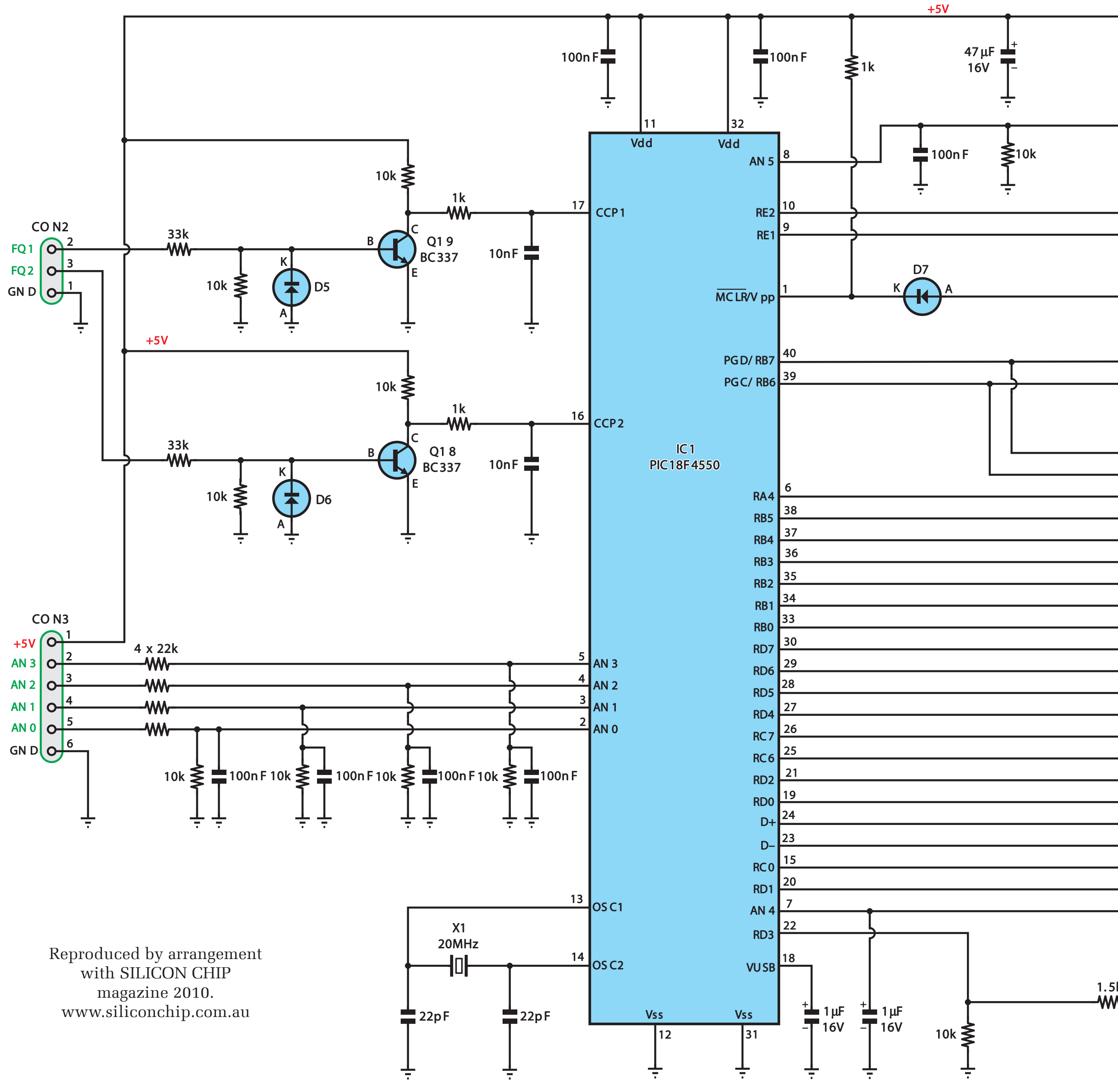


Fig.2: these diagrams illustrate some of the readouts that can be scrolled across the three 7 × 5 dot matrix displays. The battery and ambient light functions are built in, while all other functions are set-up by the user via a PC program.



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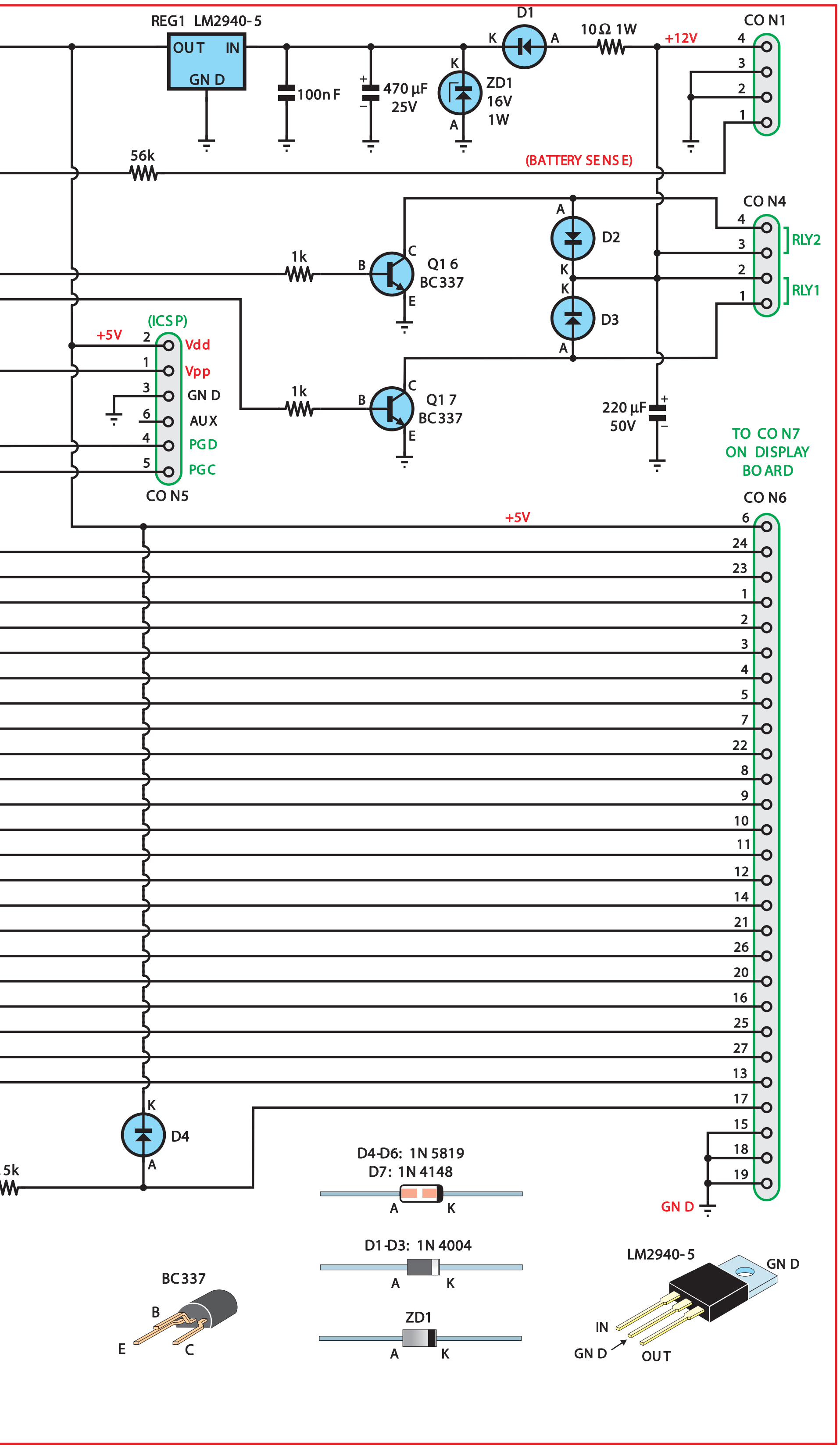
CAR SCROLLING DISPLAY MAIN BOARD

Fig.3: the main board circuitry; PIC microcontroller IC1 accepts the various analogue and frequency input signals, processes these signals and then drives the separate display board via connector CON6.

3.2) is that you lose resolution in the ADC conversion. Since the ADC is 10 bits or 1024 levels, we obtain a value of 16V/1024 or about 16mV sensitivity.

While this is plenty for most applications, you can increase the sensitivity of the input if you know in advance that your sensor has a nominal output much lower than 16V. This involves changing the 22kΩ resistor on the corresponding analogue input.

The following equation is used to get an approximate value for the resistor:



R = 2000V – 10,000
where V is the maximum voltage range required (>5V) and R will be the new resistor value (ie, to replace the existing 22kΩ resistor).

The resulting sensitivity will be approximately the value of V in mV (millivolts); eg, if V = 6, then the sensitivity will be about 6mV and the resistor value will be 2kΩ.

Since all calibration is done in software, you only need to replace the 22kΩ resistor corresponding to your analogue channel to improve the accuracy for that channel. The software does not need to be changed, as the values will be correct for your new divider when you perform the next calibration.

Oxygen sensor loading

Although the ADC inputs of IC1 have a high input impedance, the load on the analogue inputs will be the sum of the 22kΩ (or your replaced value) resistor and the 10kΩ resistor, ie, 32kΩ (or 10,000 + R).

While this loading is high enough to result in very small current draw from most sensors in your car, you should be aware that typical narrowband oxygen sensors do not tolerate more than about 10µA current load. Since the ECU will have its own current load, we should aim to draw no more than about 1µA extra from such a sensor.

This means that if you wish to connect an oxygen sensor to this project, you should omit or remove the 10kΩ resistor to ground on the corresponding analogue input. The result will be that the loading will then be the series impedance of the 22kΩ resistor and the high input impedance of IC1's ADC input.

The resulting extra current should be less than 1µA, since the ADC inputs have a typical leakage current of just 500nA. Note that there will also be negligible transient loading due the 100nF capacitor.

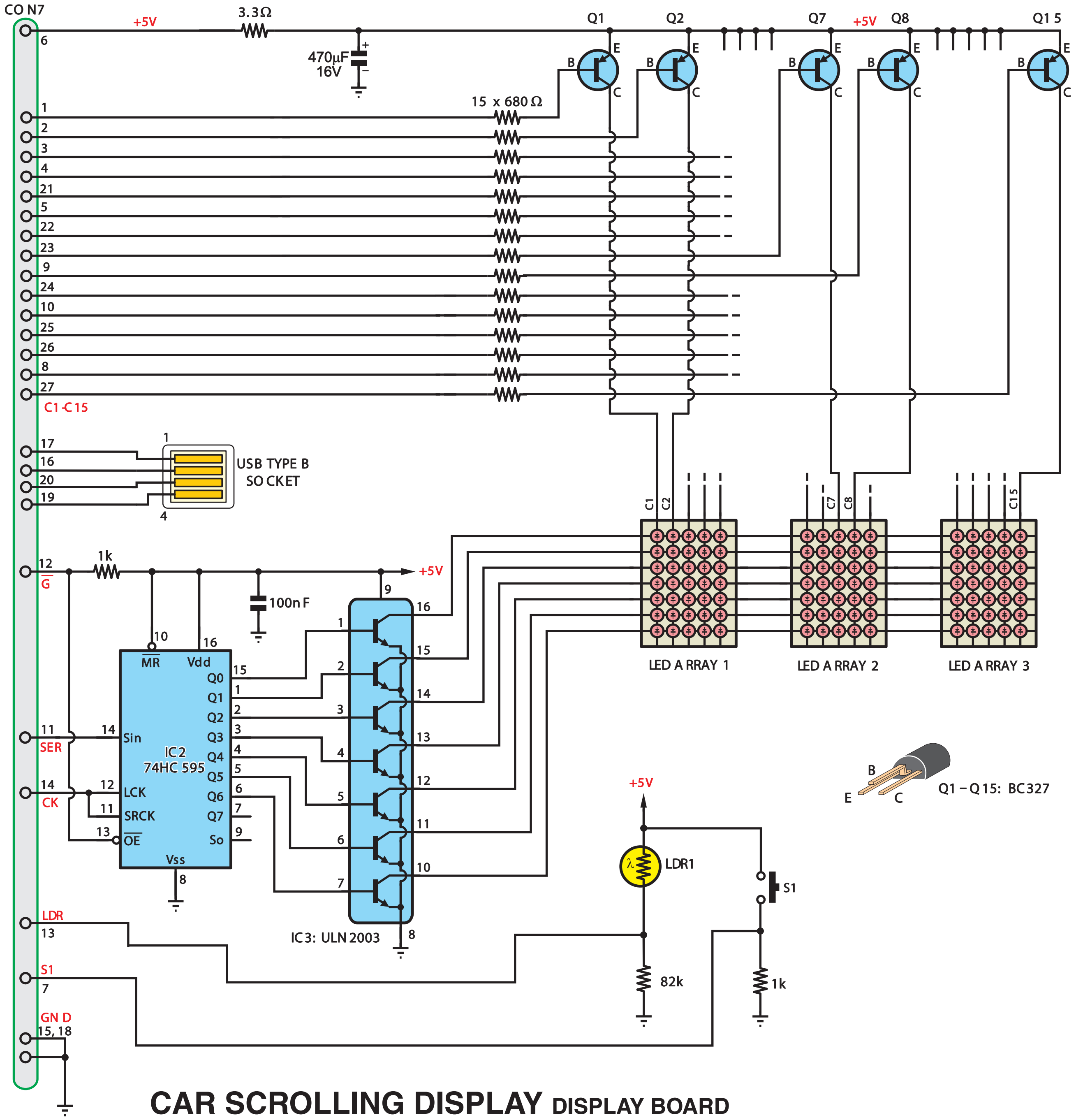
Additional input channels

There are two additional analogue channels used. One is used to measure the battery voltage at pin 1 of CON1. It has its own 56kΩ and 10kΩ voltage divider and 100nF bypass capacitor.

The other analogue channel is used to monitor a voltage divider on the display board, consisting of a light dependent resistor (LDR1) and an 82kΩ resistor. The analogue signal is at pin 13 of CON6 and is used to measure the ambient light level, to vary the brightness of the LED display.

CON4 is used to connect the relays and/or buzzers used for the limit conditions.

Each digital output from the microcontroller is applied to the base (B) of a BC337 *NPN* transistor (Q16 or Q17)



CAR SCROLLING DISPLAY DISPLAY BOARD

Fig.4: the Display Board circuit (above) uses a 74HC595 shift register (IC2) to drive the rows of the three dot-matrix LED arrays via a ULN2003 Darlington array (IC3). Transistors Q1 to Q15 switch the display columns.

via a 1kΩ resistor. Each transistor is configured as a switch, to drive the coil of the relay or a 12V buzzer. Diodes D2 and D3 clip any back-EMF spikes generated when the relays switch off, while the 220µF 50V capacitor is used for bypassing.

The microcontroller (IC1) runs from a 20MHz crystal and the two 22pF ceramic capacitors provide the correct loading. The 1kΩ resistor from the 5V rail is used to pull up the $\overline{\text{MCLR}}$ input (pin 1) of the microcontroller (this is the active low reset input). The microcontroller is reset by internal POR (power on reset) circuitry.

CON5 is for programming your own PIC microcontroller, using the PicKit2 programmer from Microchip. We used this during development of this project.

There is one further sub-circuit on the main board, consisting of a Schottky diode (D4) and two resistors (10kΩ and 1.5kΩ). Pin 17 of the 27-pin connector CON7 is the V_{USB} rail (ie, positive power from the USB port on the display board).

This will be around +5V when a USB cable is connected and 0V otherwise. This input passes through the voltage divider consisting of 1.5kΩ and 10kΩ resistors. The division factor is thus 1.15, meaning that pin 22 of IC1 will be at around 4.3V when a USB cable is connected and at 0V otherwise.

This pin is configured as a digital input (bit 3 of PORT D) which allows the firmware to detect when a USB cable is connected or disconnected.

Schottky diode D4 allows the circuit to be powered directly from the USB port and connects directly to the +5V rail. In the worst case, the V_{USB} line will be at +4.75V (5V ±5% is what the USB standard specifies) and so the +5V rail can be as low as +4.5V when powered directly from the USB port.

Diode D4 also protects against reverse polarity and prevents current flow into the USB port when the circuit is powered from a 12V battery or power supply.

Because the +5V rail can be substantially lower than +5V when powered from the USB port, you ***must*** perform any calibration with the full 12V input from the car battery. The actual voltage of the +5V rail will affect the ADC readings from the analogue channels because it is the positive reference for the ADC conversion. This will be explained in the calibration instructions, next month.

Main features and specifications

- **Can be powered** from 9V to 12V DC or from a USB port (5V).
- **Two Frequency/Duty Cycle Inputs** with frequency up to 10kHz.
- **Positive Duty Cycle Range:** 0-100%.
- **Four Voltage/Resistance Inputs Plus Battery Voltage** (the latter has its own channel).
- **Voltage Range:** 0V to 16V (greater or smaller ranges possible by changing one resistor).
- **Sensitivity with 16V scale:** approximately 16mV.
- **Best Sensitivity:** approximately 5mV (requires changing one resistor and recalibrating using the supplied PC software).
- **Two output channels** to drive external relays or buzzers.
- **Up to 10 displayed variables.**
- **Averaging or direct acquisition** mode for each variable.
- **Screen dimming on ambient light** with adjustable sensitivity and selectable minimum brightness.
- **7 × 15 dot matrix LED display** (scrolling or static display).
- **Static display** of up to 4 digits (floating point)
- **Selectable scrolling speed.**
- **On screen limit warnings** for each variable in the static display mode.
- **Software calibration** using polynomial interpolation.
- **Persistent settings** stored in non-volatile memory.
- **Easily load and store** previous settings to file on your computer.
- **Easily load and store** different calibration point files on your computer.
- **All settings changeable** using the USB port and PC host program.
- **Data logging** via the USB port; selectable variable update frequency from 0.1-8Hz; can collect 1000s of samples to a PC's hard drive.

Display circuit

Microcontroller IC1 controls the display via 27-pin connector CON6, which plugs into CON7 on the display board – see Fig.4. Fifteen of these lines control BC327 *PNP* transistors to drive the columns of the LED display.

The display board consists of three dot matrix LED modules, a 74HC595 shift register (IC2) and a ULN2003 Darlington driver (IC3). The display is multiplexed, meaning that only one column is lit at any one time. The brightness of the display is varied by changing the duty cycle of the column driving signals. The display refresh frequency is around 150Hz.

IC2 is an 8-bit shift register, and the seven least significant bits (Q0 to Q6) are used to drive the seven rows of the display. The microcontroller uses three lines – SER (data input), $\overline{G}$ (output enable) and CK (clock) – to load each row value into IC2.

The $\overline{G}$ (enable) line forces all outputs of the shift register to go tri-state. This effectively blanks the display. This is done by the microcontroller when the display is being refreshed or when the shift register is being loaded. The time that the display is disabled is so short it is imperceptible. The SER (data) line feeds the data into the shift register and is also controlled by a simple digital output of the microcontroller.

The seven bits from the shift register are used as inputs to the ULN2003 Darlington array (IC3). The ULN2003 can sink up to 500mA in total between its seven outputs.

Note that there are no current-limiting resistors for the displays. Instead, we rely on the beta limiting of the transistors via the 680Ω base drive resistors. We found that even small-value limiting resistors markedly decreased the perceived brightness of the LED display.

However, we have included a 3.3Ω current-limiting resistor on the supply rail to the entire display board. Since the display can draw substantial currents (up to 300mA peak), which can affect the +5V rail used for the positive reference to the ADC system, the firmware also turns off the display when digitising the analogue inputs. This happens too quickly to be perceptible.

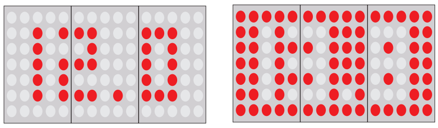


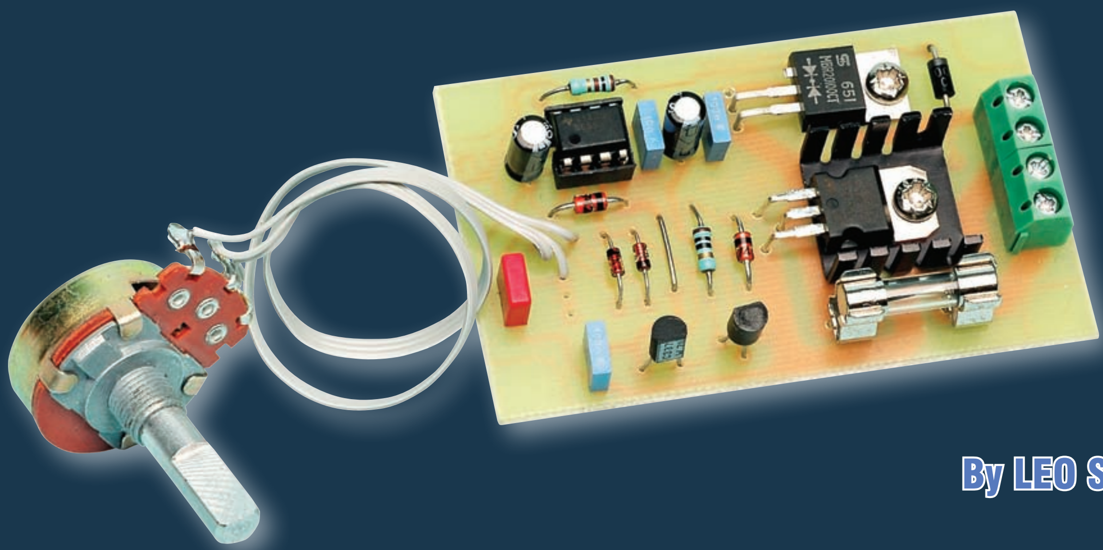
Fig.5: in-range measurements appear as shown at left, while out-of-range measurements alternate between normal and reversed mode (top right) when above maximum or flash on and off when below minimum.

An additional digital input on IC1 is used for pushbutton switch S1. It will be high when S1 is pressed and low otherwise. The signal is fed via CON6 at pin 7 and the switch is de-bounced by the software.

The USB type B socket is on the display board, and its four connections are fed to the main board via CON6.

That completes the circuit description. Next month, we give the full constructional details and set-up procedure, as well as the parts list.

12V Speed Controller OR 12V Lamp Dimmer YOU CHOOSE



By LEO SIMPSON

This handy circuit can be used as a speed controller for a 12V motor rated up to 5A (continuous) or as a dimmer for a 12V halogen or standard incandescent lamp rated up to 50W. It varies the power to the load (motor or lamp) using pulse width modulation (PWM) at a pulse frequency of around 220Hz.

WE HAVE produced a number of DC speed controllers over the years, the most recent being our high-power 24V 40A design featured in the December 2009 and January 2010 issues.

For many applications though, most designs like this are over-kill, and a much simpler circuit will suffice. Hence, we are presenting this basic design, which uses a 7555 timer IC, a MOSFET and not much else.

Being a simple design, it does not monitor motor back-EMF to provide improved speed regulation and nor does it have any fancy overload protection apart from a fuse. However, it is a very efficient circuit, and the component cost is quite low.

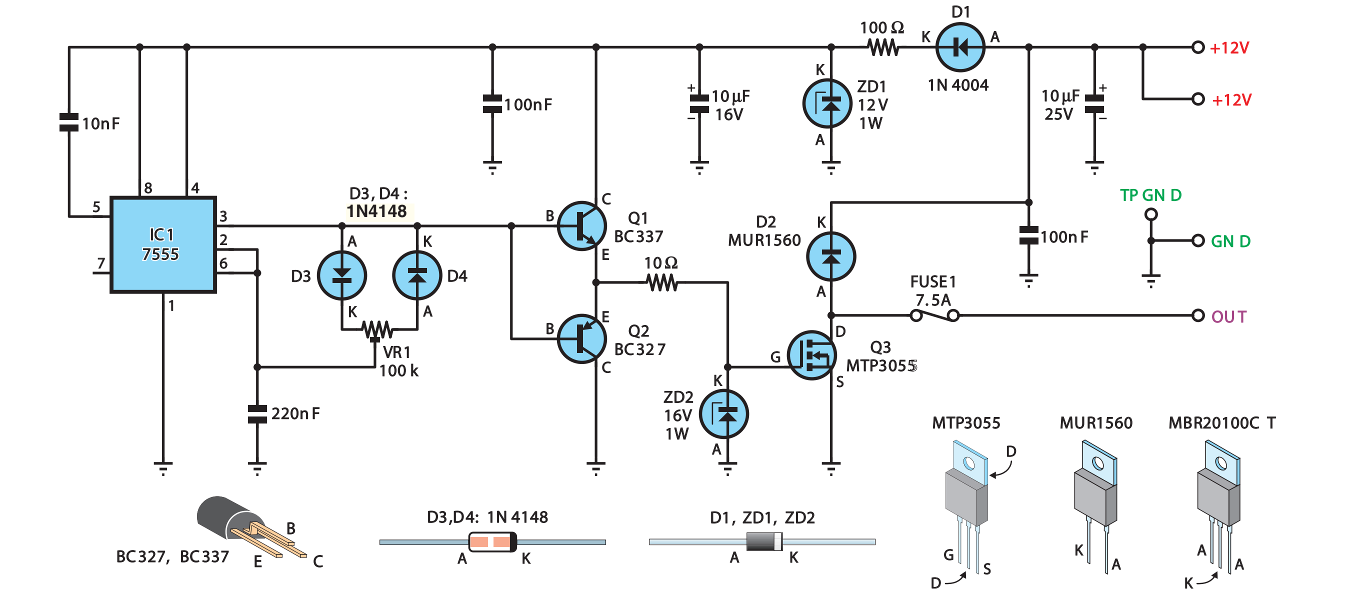
There are many applications for this circuit, which will all be based on 12V motors, fans or lamps. You can use it in cars, boats, and recreational vehicles, in model boats and model railways and so on. Want to control a 12V fan in a car, caravan or computer? This circuit will do it for you.

Halogen lamps

While the circuit can dim 12V halogen lamps, we should point out that dimming halogen lamps is very wasteful. In situations where you need dimmable 12V lamps, you will be much better off substituting 12V LED lamps, which are now readily available in standard bayonet, miniature Edison screw (MES) and MR16 halogen bases. Not only are these LED replacement lamps much more efficient than halogen lamps, they do not get anywhere near as hot and will also last a great deal longer.

By the way, you can also use this circuit to control motors with higher current ratings, say up to 10A, but we add the proviso that if the motor is likely to be pulling currents at up to its maximum over long periods, then you will need to fit a bigger heatsink to the MOSFET. Normally, such bigger motors will not pull their rated currents in most applications and the fact that you are using this circuit to reduce the speed (why else would you use it?) means that the current drain will automatically be reduced.

For most applications, however, fit the specified 7.5A fuse. If you want higher current, fit a 10A fuse and use higher current leads to connect the unit to the battery and to the load.



12V SPEED CONTROLLER/DIMMER

Fig.1: the circuit uses a 7555 timer (IC1) to generate variable width pulses at about 210Hz. This drives MOSFET Q3 (via transistors Q1 and Q2) to control the speed of a motor or to dim an incandescent lamp.

Circuit description

The PWM control circuit is shown in Fig.1, and as already noted, it is based on a 7555 timer IC and a MOSFET. The timer is wired in an unusual way, with the normal timing components connected to pins 2, 6 and 7 omitted and substituted by a 100kΩ trimpot and two diodes (D3, D4) that connect from the output at pin 3 to the timing inputs at pin 2 and pin 6. A 220nF capacitor from pins 2 and 6 to 0V completes the timing circuit, while a 10nF capacitor is connected from pin 5 to 12V.

In this configuration, timer IC1 can be regarded as an astable oscillator based on a comparator. Instead of the timing capacitor being charged from the positive supply and discharged by pin 7, the 220nF capacitor is charged and discharged from pin 3 via diodes D3 and D4 and the 100kΩ trimpot.

How it works

It works like this: when power is first applied, pins 2 and 6 will be low and pin 3 will be high. The 220nF capacitor will then be charged from pin 3 via diode D3 and the resistance between the cathode (K) of diode D3 and the wiper (moving contact) of preset VR1.

When the voltage across the capacitor reaches 0.66Vcc (ie, about 7V), the output at pin 3 goes low and the capacitor will then be discharged via diode D4 and the resistance between diode D4's anode and VR1's wiper.

When the capacitor voltage drops to 0.33Vcc (ie, about 3.4V), the output at pin 3 goes high again and the 220nF capacitor will now be charged again, as before. This cycle then continues until power is removed from the circuit.

If the wiper of VR1 is centred, the charge and discharge times for the timing capacitor will be equal and the output at pin 3 will be a square wave, or in other words, its duty cycle will be 50%, ie, 50% high and 50% low.

The operation of the 7555 timer (IC1) is illustrated in the scope shots of Fig.2, Fig.3 and Fig.4. In each case, the top trace (yellow) shows the charging and discharging of the capacitor, while the lower trace (green) shows the pulse output from pin 3.

Parts List – 12V Speed Controller/Lamp Dimmer

1 PC board, code 781, available from the *EPE PCB Service*, size 79mm × 47mm
2 2-way PC-mount screw terminals
1 TO-220 mini heatsink, 19mm × 19mm × 10mm
2 M205 PC fuse clips
1 7.5A M205 fast-blow fuse
1 M3 × 6mm screw
1M3 z 10mm screw
2 M3 nuts
1 50mm length of 0.8mm tinned copper wire (link)
1 1mm PC stake (for TP GND)

Semiconductors
1 7555 timer (IC1)
1 BC337 *NPN* transistor (Q1)
1 BC327 *PNP* transistor (Q2)
1 MTP3055 or higher rated MOSFET (Q3)
1 12V 1W Zener diode (ZD1)
1 16V 1W Zener diode (ZD2)
1 1N4004 1A diode (D1)
1 MUR1560 (or equivalent) 15A 600V fast recovery diode (D2)
2 1N4148 diodes (D3,D4)

Capacitors
2 10µF 16V PC electrolytics
1 220nF MKT polyester
2 100nF MKT polyester
1 10nF MKT polyester

Resistors (0.25W, 1%)
1 100Ω
1 10Ω
1 100kΩ horizontal trimpot (VR1)
OR
1 100kΩ linear potentiometer

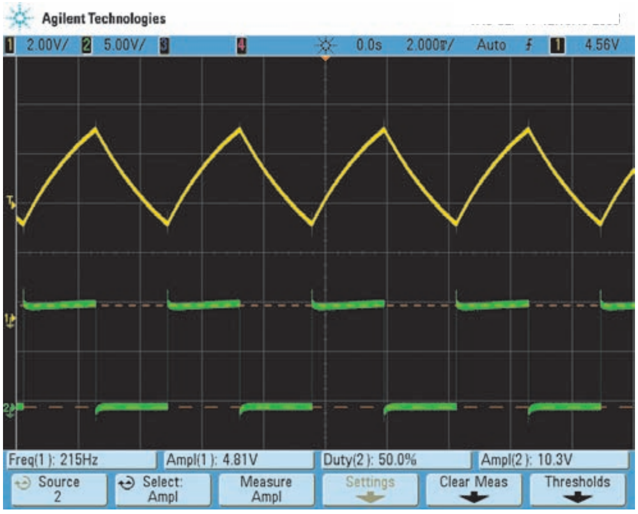


Fig.2: this scope grab shows the operation of the 7555 timer when producing a pulse waveform (green trace) with a duty cycle of 50%. The yellow trace shows the charge/discharge waveform across the timing capacitor.

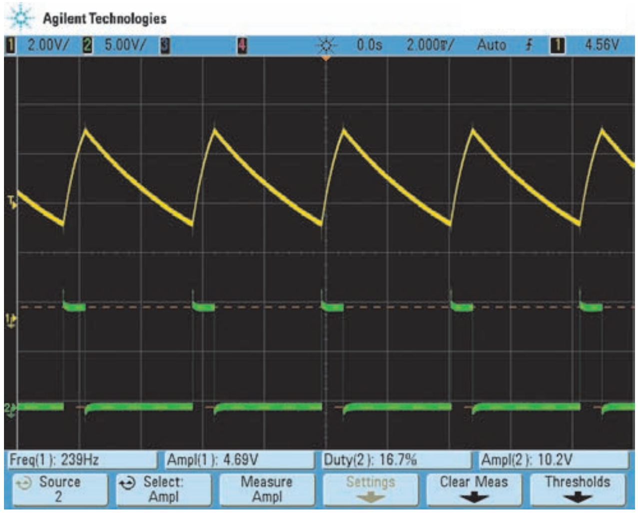


Fig.3: this scope grab shows operation of the 7555 when producing a pulse waveform with a low duty cycle (16.7%). Note the different slopes of the capacitor charge/discharge waveform (yellow trace).

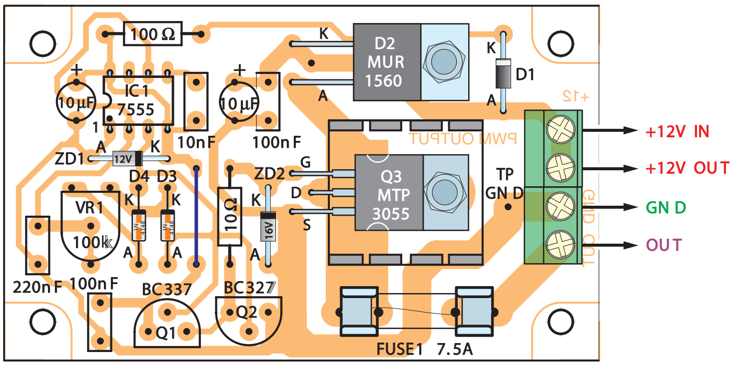
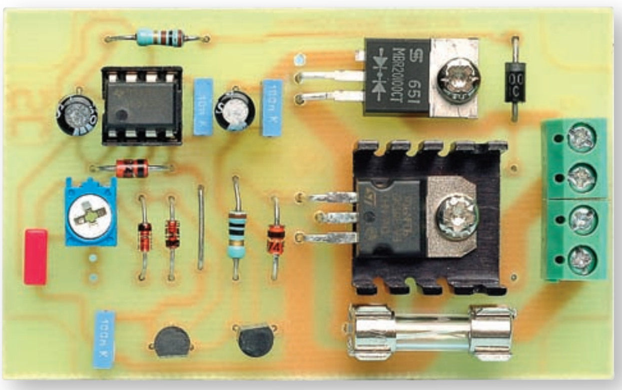


Fig.8: install the parts on the PC board as shown on this wiring diagram. Note that the board caters for both single and dual-diode packages for D2 (ie, one diode is shorted if a dual diode is used).



The prototype was assembled on an older version of the board and is slightly different in appearance to the final version shown above.

Resistor Colour Codes

Value	4-Band Code (1%)	5-Band Code (1%)
100Ω	brown black brown brown	brown black black black brown
10Ω	brown black black brown	brown black black gold brown

In the scope grab of Fig.2, we show the circuit producing a square wave, with equal charge and discharge times for the capacitor. This is shown by the yellow trace which is a typical triangle waveform.

In Fig.3, we show the circuit producing a pulse waveform with a short (17%) duty cycle, which means that for most of the time, the output at pin 3 of IC1 is low. Then in Fig.4, we show the circuit with trimpot VR1 set fully clockwise to produce a waveform that has a 100% duty cycle. In this case, the capacitor charging waveform is a classic sawtooth, with a slow charging ramp and a very sudden (almost instantaneous) discharge time. The resultant waveform at pin 3 looks pretty much like a straight line, but it actually has extremely short negative excursions corresponding to the negative slopes of the capacitor waveform.

On the buffers

OK, so now we know how the 7555 operates. Its output at pin 3 is buffered by a complementary buffer stage comprising transistors Q1 and Q2 (emitter followers) and these drive the gate (G) of MOSFET Q3 via a 10Ω resistor. The MOSFET then drives the load, which is connected between the +12V supply and the MOSFET's drain (D) terminal.

Diode D2 clamps the spike voltages which occur each time the MOSFET turns off, when driving an inductive load such as a permanent magnet motor. The adjacent 10µF and 100nF capacitors

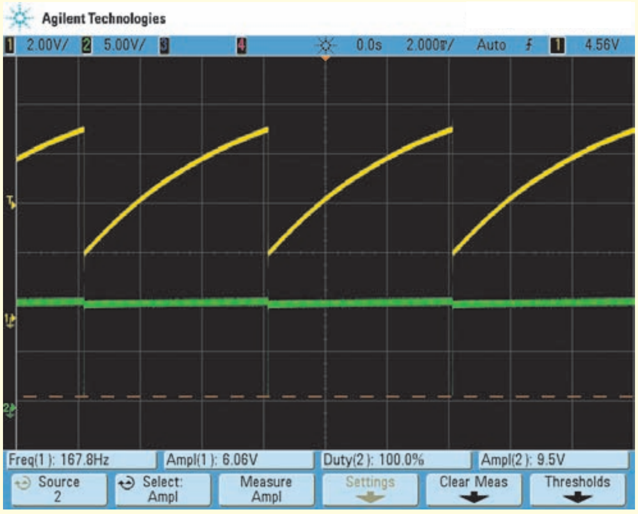


Fig.4: when adjusted for full power to the load (ie, 100% duty cycle), the timing capacitor waveform (yellow trace) is a classic sawtooth with slow charge and very steep discharge slopes.

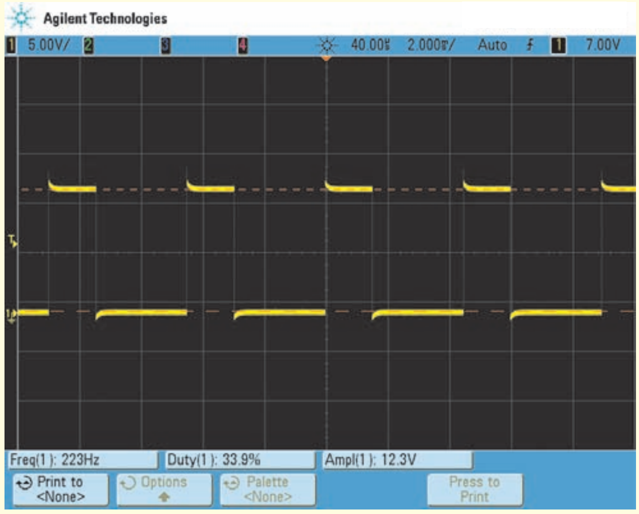


Fig.5: this scope waveform shows the voltage delivered to a resistive load such as an incandescent lamp or heat element. In this case, the pulse duty cycle has been adjusted to about 30%.

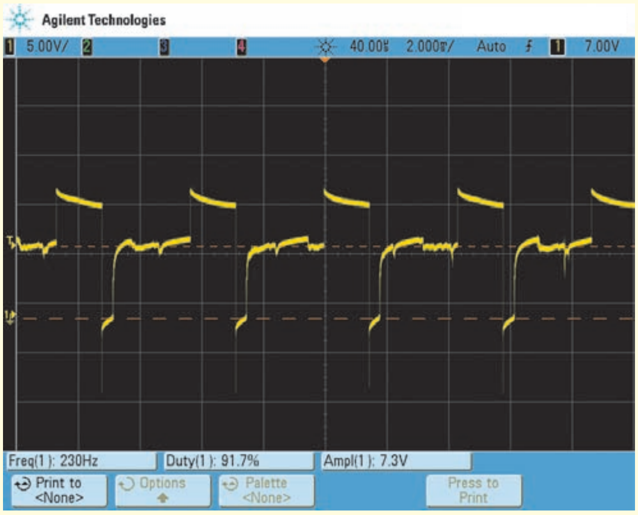


Fig.6: this is the voltage waveform across a motor running at a relatively low speed setting. The hash between 'on' pulses is due to the motor back-EMF and the interference produced by the carbon brushes.

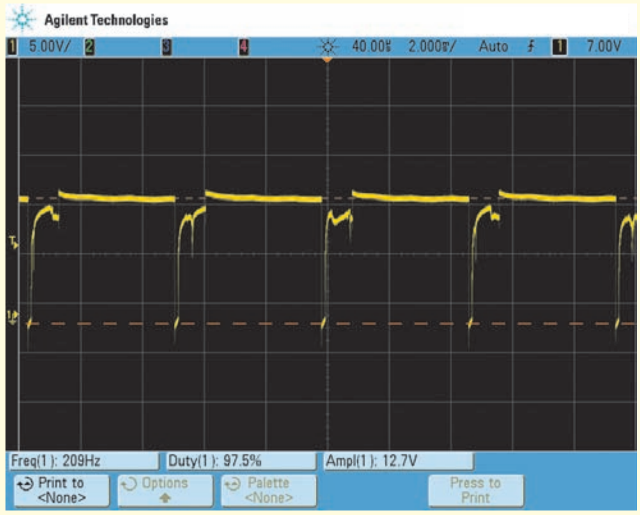
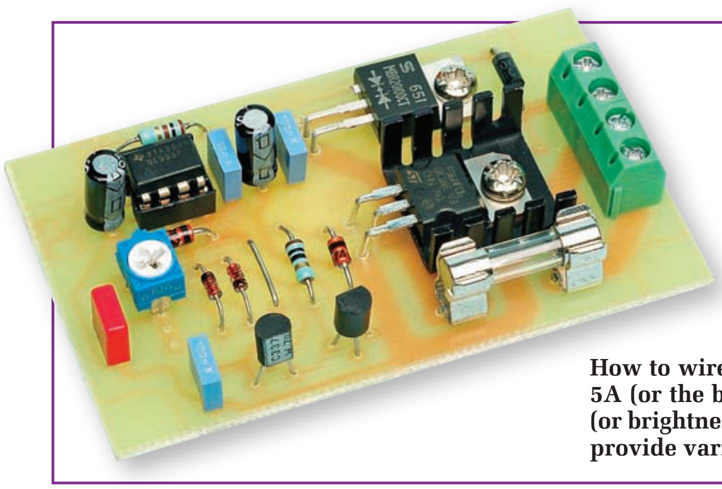
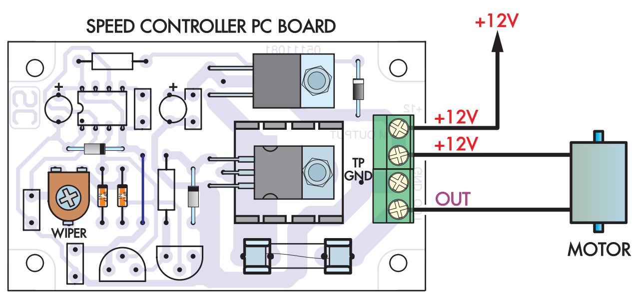


Fig.7: this is the voltage waveform across a motor running at close to full speed (ie, a high duty cycle pulse output). Once again, the hash from the brushes (shown between pulses) is very evident.





How to wire the unit to control the speed of a 12V DC motor rated up to 5A (or the brightness of a 12V lamp). Trimpot VR1 sets the motor speed (or brightness) and can be replaced with a 100kΩ rotary potentiometer to provide variable control.

across the 12V supply are there to reduce the amount of radiated interference produced by the connecting leads to the battery and the motor.

In fact, you can gauge the amount of interference the circuit produces in an AM radio. Just bring the radio close to the circuit or its leads and tune between stations. You will hear the angry buzz produced by the pulse waveform. Move the radio away by a metre or so and the interference should be non-existent when tuned to an AM station.

Power for the circuit is derived from the incoming 12V supply via diode D1 and the 100Ω resistor. Zener diode ZD1 provides basic supply regulation, while the 100nF and 10µF capacitors provide a degree of filtering.

Building it

The PWM control circuit is built on a small PC board measuring 79 × 47mm and coded 781. This board is available from the *EPE PCB Service*. If it comes in a kit it is likely to have corner cutouts so that it fits into a standard plastic zippy box measuring 82 × 53 × 32mm.

The PC board presented here has had a few changes made to it, mainly involving component spacing, diode D2 and the 4-way terminal block. In addition, the tracks to diode D3 have been altered so that this diode now faces the same way as D4.

Note that the unit pictured in this article was assembled on an old version of the PC board, so these changes aren't shown in the photos. Just follow the parts layout diagram (Fig.8) to build the unit and all will be well.

When assembling the PC board, make sure you insert the polarised components the right way around. These parts include the 7555 timer IC, the transistors, diodes, Zener diodes and the electrolytic capacitors. Fit all the small components first, followed by the fast recovery diode (D2), the fuse clips, MOSFET and the 4-way terminal block.

When fitting the two fuse clips, make sure you put them in the right way round, so that their little retaining lugs will be at each outside end of the fuse when it is inserted. **Note also that we have made provision for two different fast recovery diodes for D2, either a 2-lead SOD-59 type such as MUR1560 or BY229, or a twin-diode 3-lead TO-220 type, such as the MBR20100CT type.** In the case of the 3-lead type, there are actually two 10A diodes in the package but one of them is shorted out when the device is soldered in place.

When installing the diode, crank the leads at right angles so that they go through the board and the hole in the mounting lug lines up with the 3mm hole in the PC board. Before the diode is soldered in place, bolt it to the board with an M3 screw and nut. Do not solder the diode and then tighten the screw and nut otherwise you will stress the diode package and it will fail prematurely.

Similarly, when mounting the MOSFET, crank its leads to suit the board and mount it with a mini U-shaped heatsink. It is secured to the board with an M3 screw and nut and then its leads can be soldered.

Finally, fit the 4-way connector and the board is finished.

Testing

Before connecting the battery, carefully check your work against the circuit and the PC board wiring diagram (Fig.8). Make sure that every component is installed exactly as shown.

Next, connect a low wattage 12V lamp to the +12V and OUT terminals and apply 12V DC from a battery or mains-operated 10A DC power supply. You should be able to vary the brightness from fully on to completely off with the trimpot. If you are happy with that, you can then install the board in its final position.

By the way, if you want to fit a full size potentiometer (with knob) as a variable control instead of using a trimpot on the board, it is quite simple. Just connect the three wires from the pot instead of the trimpot and make sure that the centre (wiper) wire from the pot goes to the wiper connection on the PC board.

Finally, if you want to reduce the pulse frequency, perhaps to make the whine in the motor less audible, change the 220nF capacitor on pin 2 and pin 6 of IC1 to a larger value, say 270nF or 330nF. ***EPE***

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PLEASE TAKE NOTE

Water Pump Switch *(IU Sept '10)*

Page 56, circuit diagram. Unfortunately, the protection diode D1 across the rely coil is shown the wrong way around. The anode (a) of D1 should connect to transistor TR1's collector (c).

Ultra-LD 200W Power Amplifier *(Aug '10)*

Page 37, parts list. The type number for the 'ThermalTrak transistors (Q14, Q15) is incorrect. It should be NJL1302D, the circuit diagram is correct.

Max's Cool Beans

By Max The Magnificent

Mirror, mirror on the wall...

THIS is such a cool idea. Imagine an antique mirror hanging on the wall near your front door. Now suppose you have a visitor who is about to leave, and who pauses to check his or her appearance in the mirror. Suddenly, the image of your guest undergoes a 'Matrix-like ripple' and is replaced with a strange face saying something like 'You aren't thinking about going out dressed like that, are you?' This would be your 'magic mirror'. Actually, there are all sorts of things you can do with one of these little beauties, but first, let's explain how it all works.

The idea is that we take a flat-screen liquid crystal display (LCD), remove its outer case, and mount it into the wall such that the screen is flush with the wall. Next, we acquire a piece of special glass that acts as a two-way mirror. If we place this special glass over a black surface it will appear to be a normal mirror; if there's a light source behind the glass, however, then that light will pass through. So the idea is to take the glass, mount it in an antique picture frame, and hang it on the wall covering our LCD screen.

All we need now is a proximity detector that determines when someone is standing in front of the mirror, and a computer that we'll use to drive the display. When someone stands in front of the mirror, we want the proximity detector to send a signal to the computer, which should pause for some short delay (maybe a second or so) and then start to display whatever image, video, or other data we decide to use.

I only wish I could claim all of the credit for this idea, but – sad to relate – someone else thought about it first. You can see the original DIY Magic Mirror on their website at **http://diymagicmirror.com**. Also, you can see a video of this working on YouTube at: **www.youtube.com/watch?v=azsYhwk9LYk**.

The folks at DIY Magic Mirror have created some rather cool software that runs on your PC and can display a variety of 3D animated faces speaking prepared phrases, or saying whatever you want them to say, using a 'text-to-speech' capability. This software can also access and display (or say) information from the Internet, such as your local weather forecast, current stock prices, and so forth. The DIY Magic Mirror folks have also developed a small hardware kit that accepts inputs from a number of sensors and sends signals to your PC to control the software.

On the cheap

However, generally speaking, I prefer not to spend my hard-earned cash if I don't have to (call me 'old-fashioned' if you will). I decided to do things in a cheap-and-cheerful way. (I should mention that the guys at DIY Magic Mirror recently heard what I was up to and kindly sent me a copy of their software and hardware to play with, so I'll be evaluating both their stuff along with some 'home-grown').

The first step was to acquire the special two-way mirror glass. At the moment, I'm simply creating a proof of concept, so I followed the advice on the Magic Mirror site and ordered a 12in. × 12in. sample of this dielectric glass ($19.95 plus shipping and handling) from: **www.hiddentelevision.com/sample.htm**. Although 12in. × 12in. might not seem very large, it's sufficient to cover a 15in. diagonal LCD Monitor with a 4:3 aspect ratio, which is what I'll be playing with at first. A couple of days later a box arrived containing the (very carefully packaged) glass.

But I'm leaping ahead of myself... as soon as I'd put the phone down after placing my online order for the special two-way mirror glass, I headed out to my local technology recycling centre, which is located just around the corner from my office (this is fortunate for me since I spend so much time there). Hurray! I managed to pick up a very nice secondhand 15in. LCD monitor for only $45 (£29 approx.).

Mind games

While I was waiting for my special two-way mirror glass to arrive, I started thinking about the various ways in which I might want to use this little scamp. Depending on the amount of computing power you have available to you, you could actually do all sorts of clever (and/or silly) things. For example, a few ideas off the top of my head are as follows:

- Mount a small video camera in the frame and display the user's own image, but time-delayed by some very small amount, like one-tenth of a second (I really do want to try this effect to see what it's like).
- Using the same video camera, display the user's own image mirror-imaged (if you see what I mean).
- Using the same video camera, display the user's own image, but with a big pimple superimposed on the end of the nose (this would take a lot of computing power, especially keeping it in the same relative location as the image moved around slightly, but it would be really cool if you could do it right).

Honestly, once you start thinking about this, your imagination tends to run wild (at least, mine does). But I decided to rein myself in a bit and start with something simple. I decided that all I want is to film a series of short videos of someone whose face has some 'character'. I'm thinking that a second or so after you've started looking at yourself in the mirror, there could be a 'ripple' effect and this face could appear saying something amusing, or scary, or surreal. In fact, there's a guy in my office who sports a black handlebar moustache, who has volunteered to be in my first videos, so we'll see how that goes.

Of course, I still need the proximity detector and associated hardware and the software to run on my PC, but that's a tale for next time... Until then, have a good one!

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Catch up with Max and his up-to-date topical discussions

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SP9	25 x 3mm 1 part Led clips
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SP11	30 x 1N4001 diodes
SP12	30 x 1N4002 diodes
SP18	20 x BC182B transistors
SP20	20 x BC184B transistors
SP23	20 x BC549B transistors
SP24	4 x Cmos 4001
SP25	4 x 555 timers
SP26	4 x 741 Op-amps
SP28	4 x Cmos 4011
SP29	4 x Cmos 4013
SP33	4 x Cmos 4081
SP34	20 x 1N914 diodes
SP36	25 x 10/25V radial elect caps
SP37	12 x 100/35V radial elect caps
SP38	15 x 47/25V radial elect caps
SP39	10 x 470/16V radial elect caps
SP40	15 x BC237 transistors
SP41	20 x Mixed transistors
SP42	200 x Mixed 0.25W CF resistors
SP47	5 x Min. PB switches
SP49	4 x 4 metres stranded core wire
SP102	20 x 8 pin DIL sockets
SP103	15 x 14 pin DIL sockets
SP104	15 x 16 pin DIL sockets
SP109	15 x BC557B transistors
SP112	4 x Cmos 4093
SP115	3 x 10mm Red Leds
SP116	3 x 10mm Green Leds
SP118	2 x Cmos 4047
SP124	20 x Assorted ceramic disc caps
SP130	100 x Mixed 0.5W CF resistors
SP131	2 x TL071 Op-amps
SP133	20 x 1N4004 diodes
SP134	15 x 1N4007 diodes
SP135	5 x Miniature slide switches
SP136	3 x BFY50 transistors
SP137	4 x W005 1.5A bridge rectifiers
SP138	20 x 2.2/63V radial elect caps
SP142	2 x Cmos 4017
SP143	5 Pairs min. croc.clips (Red+Blk)
SP144	5 Pairs min. croc. clips (assorted colours)
SP146	10 x 2N3704 transistors
SP147	5 x Stripboard 9 strips x 25 holes
SP151	4 x 8mm Red Leds
SP152	4 x 8mm Green Leds
SP153	4 x 8mm Yellow Leds
SP154	15 x BC548B transistors
SP156	3 x Stripboard 14 strips x 27 holes
SP160	10 x 2N3904 transistors
SP161	10 x 2N3906 transistors
SP164	2 x C106D thyristors
SP165	2 x LF351 Op-amps
SP166	20 x 1N4003 diodes
SP167	5 x BC107 transistors
SP168	5 x BC108 transistors
SP172	4 x Standard slide switches
SP173	10 x 220/25V radial elect caps
SP174	20 x 22/25V radial elect caps
SP175	20 x 1/63V radial elect caps
SP177	10 x 1A 20mm quick blow fuses
SP178	10 x 2A 20mm quick blow fuses
SP181	5 x Phono plugs - assorted colours
SP182	20 x 4.7/63V radial elect caps
SP183	20 x BC547B transistors
SP186	8 x 1M horizontal trimpots
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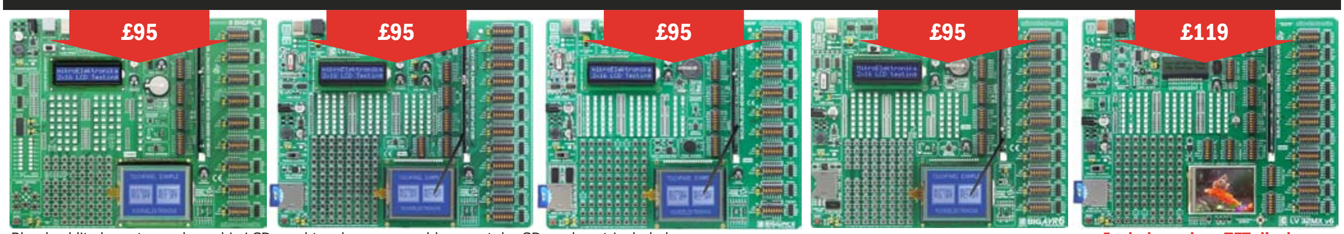

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TechnoTalk

Futures, Follow-up and Feedback

Mark Nelson

This time we've got two ground-breaking technologies, an amusing follow-up to a previous article and reader feedback too. Mark guides us through this topical mix of applied electronics.

The solution is nanowires

MUCH has been made of the way that iPads, BlackBerries, Kindles and other reading gadgets substitute electronics for paper. All clever stuff of course, but all of these devices are essentially rigid, meaning you cannot fold or curve them to fit in an already stuffed jacket pocket or the crowded glove compartment in your car. But now comes the prospect of equivalent products that you could squeeze anywhere, with all the flexibility of real paper.

'Imagine a foldable iPad,' says Benjamin Wiley, an assistant professor of chemistry at North Carolina University, where researchers have perfected a simple way to make tiny copper nanowires in quantity. These cheap conductors are small enough to be transparent, making them ideal for thin-film solar cells, flat-screen TVs and computers, and flexible displays.

Existing methods of producing display screens are becoming more expensive thanks to the increasing demand for the materials used. In addition, the production process is inefficient and the materials are brittle.

'If we are going to have these ubiquitous electronics and solar cells,' continues Wiley, 'we need to use materials that are abundant in the earth's crust and don't take much energy to extract.' He points out that there are very few materials that are both transparent and conductive, but copper, which is a thousand times more abundant than the indium used currently, can be used to make a film of nanowires that is both transparent and conductive.

Because the process is water-based, and because copper nanowires are flexible, Wiley thinks the nanowires could be coated from a solution in a roll-to-roll process, like newspaper printing. This would be much more efficient than the current production process, and it operates at normal room temperature.

This news comes at the same time as technology company Plastic Logic (based in Dresden, Germany, but born out of the Cavendish Laboratory, Cambridge University) announced that it was scrapping its e-book reader project in favour of a second-generation product, tagged the ProReader. Both designs employ a flexible backplane combined with a frontplane material ('electronic paper') to make a flexible display.

Green light for all-photonic data switching

If your broadband comes from Virgin Media you'll know that the company makes great play of the billions it has invested in building its fibre optic network. 'It's the most advanced way to enjoy broadband', states the company. 'Totally future-proof', the network sends vast amounts of information literally at the speed of light, with delivery speeds of up to 50Mbit/second.

However, few networks are entirely optical, and not many customers have fibre all the way into the home. The necessary signal conversion from optical to electrical (and vice versa) slows down data transmission, which is why a new development announced in *Nature* magazine by Prof. Holger Schmidt, an electrical engineer at the University of California at Santa Cruz, is exciting network designers. Schmidt's work employs vapour-filled optical waveguides on silicon chips to process and switch data streams encoded in light on the chip without conversion into an electrical state.

'Potentially, we can use this to create all-optical switches, single-photon detectors, quantum memory devices, and other exciting possibilities,' he says. What makes his development so interesting is that it's very difficult normally to slow down or stop the photons of light. Nevertheless, his technique achieves this with a silicon chip created using ordinary manufacturing techniques. It's a pretty exotic chip, granted, but it does not have to be operated in a laboratory environment, and according to Schmidt, it can change the speed of light just by adjusting the power control.

He continues, 'Slow light and other quantum coherence effects have been known for quite a while, but in order to use them in practical applications we have to be able to implement them on a platform that can be mass-produced and will work at room temperature or higher. That's what our chips accomplish.'

The biter bit

Last time, I mentioned the bizarre people who expect full mobile coverage wherever they roam, but oppose the construction of new base stations. One such person is Sandra Rickell of the 'Stop The Melton Mast' action group in Leicestershire. These protesters are campaigning to stop a Vodafone tower mast going up on the Grange Drive estate in Melton Mowbray.

Unconvinced by an assurance from the Mobile Operators' Association, that there are no established adverse health effects from mobile phone base stations operating within the guidelines set by the International Commission on Non-Ionizing Radiation Protection, some of their 'very concerned residents' have been living in a caravan for 19 months in a bid to fend off Vodafone's construction team.

Said Ms Rickell last March, 'We really believe mobile Internet is both an unnecessary luxury and harmful to health.' But fast forward to September, when she was mobilising support for a protest march on Downing Street, the irony was awesome even if it was lost on her. Here's the email she sent her supporters: 'Please could you confirm if you are able to attend by ringing/texting 079xx xxxxxx. I'm afraid my landline is out of order.' Ouch!

Letters, we get letters

Ben Morris sent an interesting letter from Eccles, where the cakes come from. Wikipedia tells me these were first sold in that town in 1793, and their alternative names include 'Fly Pie' and 'Fly's Graveyard', but in fact, Ben's letter was not about cakes, but to tell us how he enjoys 'ratting' old equipment.

Writes Ben, 'Readers may be interested in something I found a use for years ago, and I am still using to this date. In an old TV there were a lot of chokes that came to my attention as a 'messer'. They reminded me of the old moving-iron magnets in the ex-forces headphones that were around in the 1960s. The only difference being that the chokes used just a coil, with no magnet.

'I figured that if there was a magnetic field for the coil to work on, the result might well produce a usable signal for, in my case, a recording mixer. So I wired it up, taped it to the back of a loudspeaker's magnet, turned up the fader and – hey presto – the coil was reacting superbly to the changing field of the speaker.

'This set-up provides good-quality sound and allows a good deal more separation from other sound sources than a microphone. Curiously, I've never heard of anyone in the recording industry using this method, preferring to put an extremely expensive mic at the mercy of some crazy muso (there are a few!).

'There are things that I and others, especially the late great Telstar man, Joe Meek, used to do and in some cases probably still do. Maybe a series for the mag is in there somewhere! Thanks for a great mag, which is the one that hangs around the longest!'

Thanks for your kind words, Ben, which are much appreciated by all of us at EPE *magazine. And if anyone else would like to comment on this article or any others, don't hold back – just email/write in!*

USB Clock With LCD Readout

Part 2: By MAURO GRASSI

Last month, we detailed the circuit of the USB Clock and showed you how to build it. This month, we describe the software installation and how it is used. We also describe how to synchronise your PC to an internet time server and how to synchronise the USB Clock to the PC each time the PC boots up.

HAVING built the hardware, the next step is to install the necessary driver. The following outlines the steps for Windows XP, but other Windows versions, including Windows Vista, should work similarly.

The first step is to download the Microchip installer (**MCHPFSUSB_Setup_v1.3.exe**) from the *EPE* website (**www.epemag.com**) and run it. Note that you must use version 1.3, as older or newer versions may not be compatible. When you run the installer, this will copy the driver to the C:\MCHPFUSB\PC\MCHPUSB Driver\Release folder.

Subsequently, when you first connect the USB Clock to your computer, Windows will recognise the device as a 'Microchip Custom USB device'. The 'Found New Hardware' dialogue will then appear (see Fig.7) and you should select the 'No, not this time' option and click 'Next'.

At the following dialogue, select 'Install from a list or specific location' and click 'Next' again to bring up the dialogue shown in Fig.8. Select 'Search for the best driver in these locations' and enable the 'Include this location in the search' box.

Now click the 'Browse' button. In the 'Locate File' dialogue that appears, navigate to where the MCHPUSB files were installed (normally it will be C:\MCHPFUSB\PC\MCHPUSB Driver\Release folder) and select 'mchpusb.inf'. Click 'Next' and Windows will then install the driver.

If the driver is installed correctly, you should be able to see the 'Microchip Custom USB Device' entry in Device Manager (provided the USB Clock is connected), as shown in Fig.9 (Control Panel -> System -> Hardware Tab -> Device Manager tab).

Installing/using usbclock.exe

Once the driver has been installed, you can control the USB clock using the **usbclock.exe** program. The first step is to download this program from the *EPE* Library site (accessed via **www.epemag.com**), unzip it and copy it to a suitable folder (eg, create a folder called 'usbclock').

Usbclock.exe is a simple program that's run from the Command Prompt dialogue (formerly known as a DOS box). It's simply a matter of navigating to the folder where the program resides, then typing **usbclock** to synchronise the USB Clock with the clock on the PC.

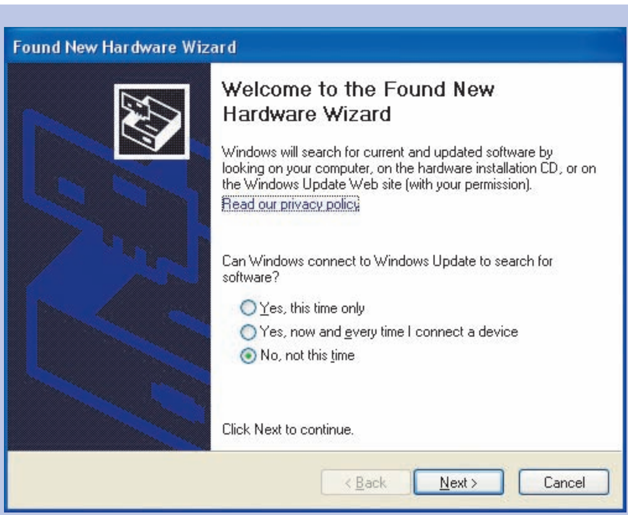

Fig.7: this is the dialogue that appears the first time the USB clock is connected to the PC. Select the option shown and click the 'Next' button.

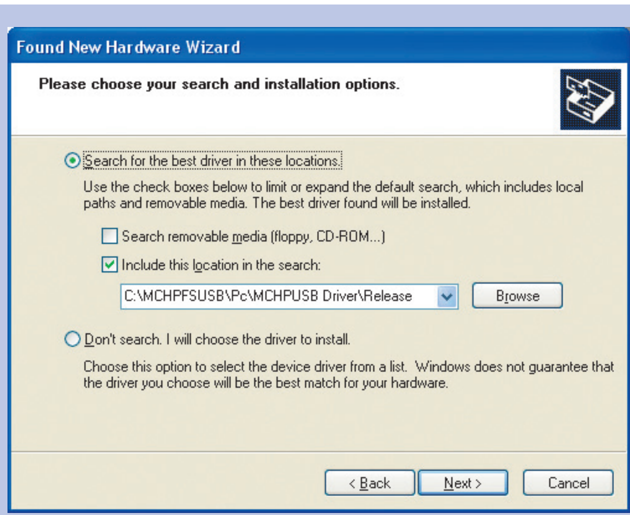

Fig.8: selecting 'Install from a list or specific location' brings up this dialogue. Select the options shown and click the 'Next' button. Windows then installs the driver.

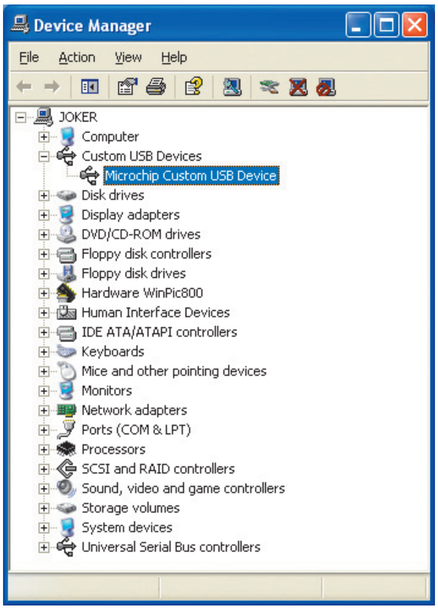

Fig.9: if the driver is installed correctly, this entry appears in Device Manager.

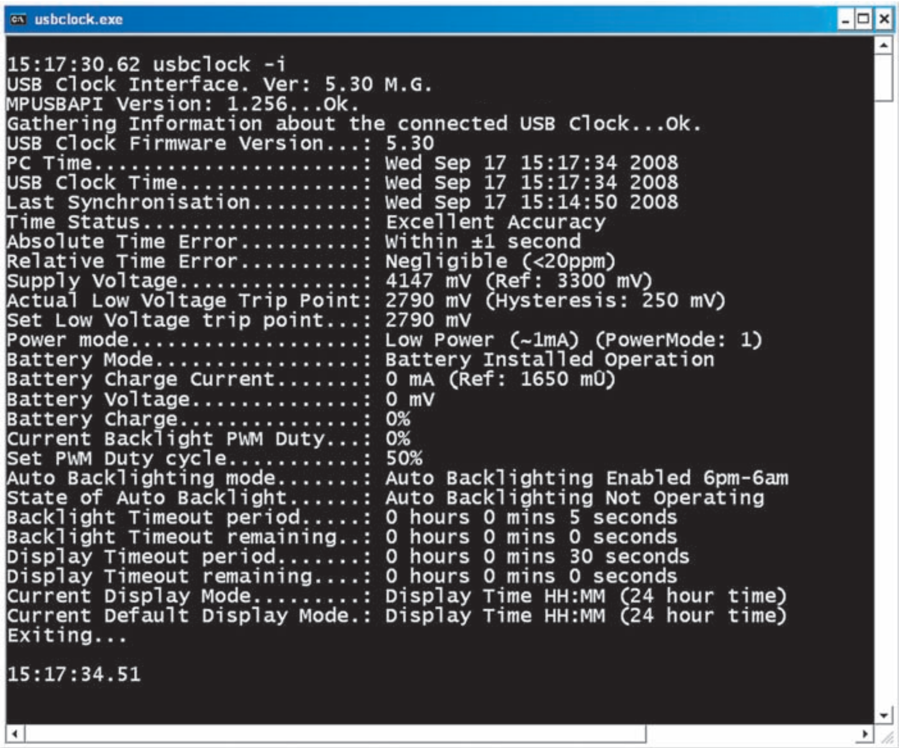

Fig.10: the USB clock is synchronised with your PC's time by running the *usbclock.exe* program from a command window. This screen grab shows the output after running *usbclock -i* to view all the clock's operating settings.

For other functions, simply enter **usbclock x** at the command prompt, substituting the appropriate switch for the 'x'.

Table 3 shows the various command line switches and their functions. Among other things, you can view the current operating settings (**-i**), change the PWM duty cycle (and thus the brightness) of the backlight (**-p:X**), set the backlight timeout period (**-t:X**), set the auto-backlighting on or off (**-a:X**) and change the display format from the default 24-hour time to 12-hour format (**-y:X**).

Fig.10 shows a typical example of the screen that appears when the **usbclock** program is run.

Driving the USB Clock

There's only one control on the front panel of the USB Clock and that's pushbutton switch S1. You simply press S1 to turn on the backlight. This will be turned on for the duration of the timeout period (set by running the **usbclock –t:X** command) at the set PWM duty (set by running the **usbclock –p:X** command).

Pressing S1 again allows you to scroll through the different display modes of the clock. You can then see the date displayed on the clock as well as other settings. The display modes were shown in Table 2 last month.

After the display timeout period expires (from the last switch press) the display mode will revert to the default display mode (set by running the **usbclock –z:X** command). The display timeout can be changed by running the **usbclock –d:X** command.

Synchronising your PC to a network time server

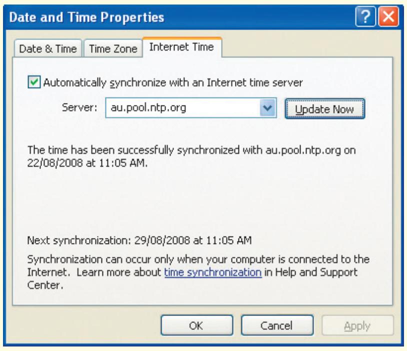

Fig.11: this WinXP dialogue is used to enable your PC to synchronise with an internet time server.

THE NTP (network time protocol) is used to synchronise 'network-enabled' devices (such as your PC) with remote time-servers. Basically, a time-server is a server computer that derives its time from a very accurate reference clock and distributes this time to other computers. The most common time reference for these servers is a GPS clock or GPS master clock.

To ensure that your PC's local clock (and by extension, your USB clock) always shows the correct time, it's necessary to enable NTP time synchronisation in Windows. When this is done, your PC will synchronise with the selected Internet time server once a week, although you can also perform manual updates as well.

NTP synchronisation is enabled in Windows XP as follows:

1) Double-click the clock in the bottom right corner of the system tray.
2) Click the 'Internet Time' tab on the resulting 'Date and Time Properties' dialogue to bring up the dialogue shown in Fig.11.
3) Select 'Automatically synchronise with an Internet time server'.
4) Enter a valid NTP server domain name into the space provided. The **au.pool.ntp.org** server should work for users in Australia but you can also select one of the default overseas servers from the drop-down list. Alternatively, there are many other NTP servers available and you can easily do an internet search for them. A good place to start is **www.pool.ntp.org**
5) Click on the 'Update Now' button to test the synchronisation. The Windows NTP service may fail if a firewall is blocking it, although NTP may also fail sporadically even when set-up correctly, due to lost packets or handshaking timing out.

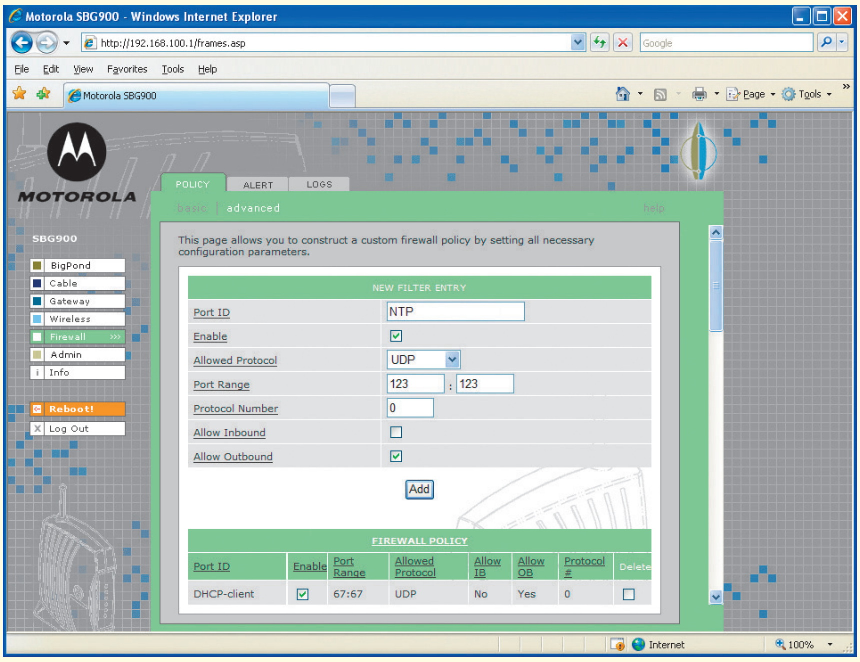

Fig.12: if you have the firwall enabled on an ADSL or cable modem/router, then you will have to enable outgoing UDP connections on port 123. This screen grab shows the set-up for a Motorola SBG900 cable modem.

Punching through the firewall

NTP uses UDP port 123, so you must ensure that your firewall is not blocking outgoing traffic on this port. If it is, NTP synchronisation will fail consistently and you will have to change the firewall's settings.

The Windows XP and Vista firewalls allow all outgoing traffic and will work by default. By contrast, other third-party firewalls often block outgoing connections on port 123 and will have to be modified.

Do a search on the Internet to find the appropriate settings for your particular firewall (or check the manual). Note that you only need to enable outgoing UDP traffic on port 123 (not incoming).

Similarly, if you have the firewall enabled on your ADSL (or cable) modem/router, then you may need to modify its settings as well. Fig.12 shows the settings for a Motorola SBG900 cable modem. Again, you only need to allow outbound UDP traffic on port 123.

There's one more feature we need to explain and that's the auto backlighting mode. If enabled (**usbclock -a:1** or **usbclock-a:2** turns it on, while **usbclock -a:0** turns it off), the unit automatically turns the backlight on at the set PWM duty cycle, depending on the time of day (provided that the USB Clock is running on USB power).

If in automatic backlight mode 1, the backlight will turn on between 6pm and 6am. **This means that if you have the USB clock connected to a powered hub, the backlight will come on automatically at night.** By contrast, in mode 2, it will be on all day.

The auto backlighting will not work when the USB clock is running from battery power. In that case, you will have to turn the backlight on manually by pressing S1.

Tweaking the charging current

The charging current depends on the reference value for the sense resistor. If you wish, this reference value can be changed (to give a more accurate

Command	Function	Example	Result
usbclock or **usbclock -s**	Synchronises the USB clock with the local clock on your Windows PC.	**usbclock**	The windows time will be synchronised with the USB clock.
usbclock -i	View all relevant operating settings of the USB clock.	**usbclock -i**	You will be able to see all the operating settings of the USB clock on your PC. An example screen shot is shown in Fig.10.
usbclock -p:X, where X is a number from 0 to 100.	Sets the PWM duty for the backlight. The higher the number, the brighter the backlighting will be and the greater the power consumption. Note that for values below about 15%, the backlight will not be visible.	**usbclock -p:80**	Sets the backlight PWM duty to 80%.
usbclock -t:X	Sets the time-out period in seconds for the backlight. When switch S1 is pressed, the USB Clock will light the backlight. After the time-out period expires, the backlight dims to off.	**usbclock -t:60**	Sets the time-out period to one minute.
usbclock -d:X	Sets the display time-out period in seconds. When this expires, the display reverts to the default display mode.	**usbclock -d:120**	Sets the display time-out period to 120 seconds (two minutes).
usbclock -m:X where X is the number of one of the display modes in Table 2.	Set the USB Clock's display mode for the display time-out period. The clock then reverts to the default display mode.	**usbclock -m:0**	Sets the display mode to display the time in HH:MM (hours, minutes) format.
usbclock -v:X where X is in mV	Sets the USB Clock's reference voltage.	**usbclock -v:3300**	Sets the reference voltage to 3.3V.
usbclock -c:X where X is in mΩ	Sets the USB Clock's sense resistor value.	**usbclock -c:1650**	Sets the sense resistor reference value to 1.65Ω.
usbclock -z:X where X is the number of one of the display modes in Table 2.	Sets the USB Clock's default display mode (and the display mode).	**usbclock -z:1**	Sets the display to show the date.
usbclock -l:X where X is in mV between 2170 and 4500mV.	Sets the USB Clock's low-voltage trip point.	**usbclock -l:2400**	Sets the low voltage trip point to 2.4V. If it is set too high, the backlight will be turned off too soon.
usbclock -a:X where X is either 0 (disable) or 1 (enable 6pm to 6am) or 2 (all day).	Sets the USB Clock's auto backlighting on or off.	**usbclock -a:1**	Sets the backlight to automatically turn on between 6pm and 6am.
usbclock -y:X where X is either 0 for 24-hour time (default) or 1 for 12-hour time.	Sets the USB Clock's time display mode (24hr or 12hr).	**usbclock -y:1**	Sets the USB Clock to 12-hour time.
usbclock.exe -r	Resets the USB Clock.	**usbclock.exe -r**	Resets the USB Clock and all settings are restored to default values.

Table 3: the command line switches for the *usbclock.exe* host program. The USB Clock synchronises its time with your PC's clock when this program runs without any switches and the program can also be set to run automatically when the PC boots.

Making Usbclock.exe Run Automatically

The USB Clock does not synchronise its time automatically with the PC just because it is connected to the PC via a USB cable. To do that, you have to run the **usbclock.exe** program (ie, by typing **usbclock** and pressing the Enter key at the command line).

If you wish, you can automate this procedure by having Windows run **usbclock.exe** each time the computer boots up. This is done by placing a shortcut to the program in the Start-up folder, as follows:

1) Create a shortcut to the usbclock.exe program by right-clicking it and dragging it to the desktop.
2) Copy or move this shortcut to the **C:\Documents and Settings\YourUserName\Start Menu\Programs\Startup** folder (YourUserName is your user account name).

Once the above steps have been completed, the **usbclock.exe** program will automatically run each time Windows boots up and thus synchronise the USB Clock to the PC's clock.

Note that you should also set up your PC's local time to synchronise automatically with an Internet time server, to make sure that your PC's clock (and thus your USB Clock) is always accurate. The way to do this is set out in the separate panel: 'Synchronising your PC with a network time server'.

How the circuit conserves power

One important feature of the PIC-18F4550 is its support for low-power managed modes. Although the use of CMOS ICs is important for minimising power consumption, much of the power conservation is achieved in the firmware

Basically, the microcontroller will respond to interrupts and then go into idle mode, resulting in very low power consumption. In idle mode, peripherals like the screen refresh timer and the timekeeping timer still operate, but the CPU is switched off. An interrupt generated by the peripheral will wake the CPU. The interrupt will then be serviced, after which the CPU reverts to idle mode again.

In normal operation without the backlighting, the current consumption is less than 1mA. This means that the clock should keep running from battery power for at least a few weeks before the batteries need recharging.

By contrast, the backlight draws around 200mA at 100% duty-cycle. This reduces to around 100mA at 50% and 80mA at 30% duty-cycle.

In battery mode, the backlight is turned on by briefly pressing S1. It will then stay on for the duration of the timeout period (this can be set by running the **usbclock.exe** program using the **-t** option, as explained below).

After the period expires, the backlight quickly dims down and turns off. The backlight duty cycle is also set by running the **usbclock.exe** program, this time using the **-p** option.

In addition, as mentioned previously, the microcontroller automatically reduces the duty cycle if it detects that the supply voltage rail is buckling under the load (this will only happen when the backlight is used when running from battery power).

Basically, the microcontroller sets a low-voltage trip point, with an interrupt occurring if the supply voltage drops below this point when S1 is pressed. When that happens, the microcontroller immediately reduces the PWM duty cycle of the backlight.

As a result, if the batteries are sufficiently discharged, the backlight will not turn on when S1 is pressed.

Going one step further, if the microcontroller detects that the supply voltage is below the trip point when the backlight is not being driven (ie, 0% duty-cycle), then the firmware will go into an extended power conservation mode (extra-low power). In this mode, the main priority is to keep the real-time clock updated, while the display will show ‘Lo’ to indicate a low battery.

The firmware will subsequently exit this mode when the USB clock is connected to a PC and the battery begins charging again.

If the supply voltage drops even lower than this, the firmware assumes that power is soon to be lost or that the battery is too discharged to provide power. In this case, the firmware instructs the microcontroller to go to ‘sleep’.

In this state, the CPU and all peripherals are turned off, markedly reducing the power consumption to just microamps. This prevents the battery from discharging even further.

Of course, at this point, the timekeeping fails. However, it is subsequently synchronised the next time the USB clock is connected to the PC (provided the PC is operating).

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charging current readout) by running the **usbclock -c:X** command.

The default value is 1.65Ω, which is the nominal resistance of the two parallel 3.3Ω resistors on the PC board. If the resistors don’t measure 1.65Ω, you can tweak the reference value to match their actual value. Normally, however, you don’t need to worry about this unless you’re very fussy about accurate charging current readings.

Similarly, the supply voltage reading depends on the accuracy of the 3.3V reference voltage. In practice, this may be slightly off due to manufacturing variations of IC1. It should be close to 3.3V, and so the default value of 3.3V should be adequate in most cases.

If necessary, you can change the reference voltage (using the **usbclock -v:X** command) to increase the accuracy of the voltage reading. It should match the voltage at pin 19 of IC1, as measured using a voltmeter. *EPE*

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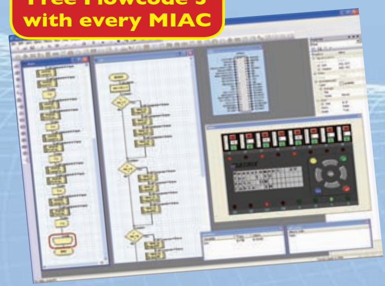

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Recycle It!

BY JULIAN EDGAR www.julianedgar.com

Automotive High Intensity Discharge Lighting

THESE days, the rate of technology turnover is so great that what still remains expensively available new can sometimes also be found at the rubbish dump. Of course, that doesn't apply to all technologies, but it does with the topic I'm covering this month – high intensity discharge (HID) lights from cars.

HID lights

HID headlights have been fitted to cars for about the last decade, starting with only very expensive cars, the technology has now been widely adopted by cheaper cars.

Advantages of HID lighting include a higher colour temperature (resulting in better colour rendition), higher efficiency and a very long bulb life.

The systems use metal halide lamps whose filling comprises mercury, metal halides and xenon. When a high ignition voltage is applied to the electrodes, the xenon gas in the quartz bulb emits light. The voltage initially applied varies from manufacturer to manufacturer, but is typically 20kV.

The powerful starting pulse gives the very quick start-up illumination required in a headlight application, with the xenon gas almost immediately emitting visible light. As the temperature of the bulb rises, the mercury vaporises, allowing the discharge to occur. Subsequently, the metal halides in the mercury arc separate and the lamp achieves full brightness. Full illumination occurs when the quartz bulb reaches its operating temperature of almost 1000K.

HID lamps develop almost twice the intensity of their incandescent halogen equivalents.

The colour temperature of the HID lighting is also higher than conventional incandescent halogen lamps, with relatively large components of green and blue wavelengths emitted, giving the light an appearance very similar to sunlight.

The life of the bulbs is quoted as being up to 50 times that of an equivalent automotive halogen bulb. In addition, if failure does occur, it is not of the sudden type experienced with incandescent lamps.

In practice, the systems consist of an electronic ballast, special HID bulb and interconnecting cables that are usually heavily insulated. However, in some systems, the ballast is split into two parts, with one part mounted on the back of the bulb and the other part mounted remotely.

Uses

So that's what they're like – but how can you use them out of cars?

The use that most appeals to me is in a house (or other dwelling) that uses renewable energy – and so has a 12V battery bank available. The excellent colour rendition and sheer brightness of HID lights means that when a powerful directional light is needed, nothing else currently comes close. For example, in a workshop using renewable energy, these lights would be quite brilliant (pun intended) at lighting fine detail work, like soldering and machining.

Here is the salvaged headlight – it came from the local rubbish dump. It's not immediately obvious that it uses a high intensity discharge (HID) light, but the convex glass lens makes it worth collecting anyway. Note the broken cover glass – the reason why it was discarded.

We do **NOT** recommend ex-automotive HID lights for portable or outside use. These lights use dangerously high voltages that are potentially lethal, especially if water enters them. Never touch a working HID system and ensure that in use, others also cannot touch any part of it except an on/off switch on the 12V supply side.

Incidentally, another advantage of these lights in a renewable energy situation is that their intensity does not change as battery voltage falls – the salvaged light operated at full brightness down to a measured 10V.

Sourcing lights

You are unlikely to come across salvageable HID lights at a normal yard disassembling cars. And, you're also unlikely to want to pay the 'top dollars' still commanded for working HID lights from a prestige car breaker! Instead, there are two avenues open to you.

The first is to visit workshops that specialise in repairing crashed, expensive cars. Invariably, damaged headlights are replaced as complete units – so even if there's just a minor scratch in the cover glass, the whole headlight will be replaced.

If the glass is broken, or a reflector is damaged, the light is likely to be thrown away – HID bulb, ballast and wiring included! That's obviously the light that you should aim to get – if you strike up a relationship with the repair business, it's unlikely to cost you anything.

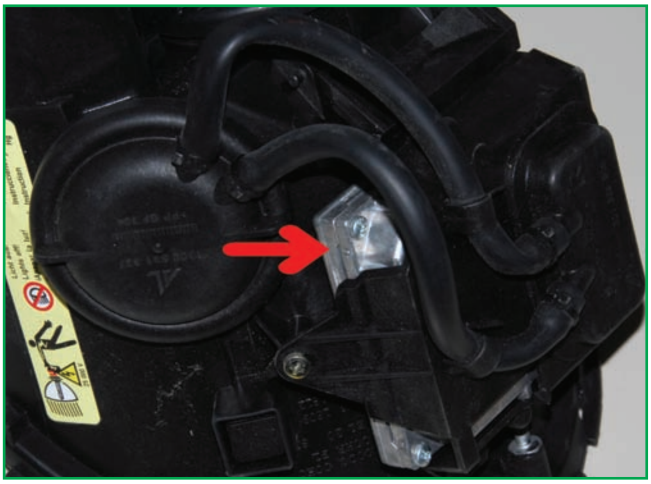
The other avenue is to buy new. But didn't I say that HID headlights cost a mint? They do, but out of China you can buy HID headlight upgrade kits relatively cheaply. These don't have reflectors, but do have the bulb, ballast and interconnecting wiring. I have bought several on eBay and the landed cost has been quite cheap.

There is a third avenue – but you need to be lucky. I was wandering around at my local rubbish tip (doesn't everyone?) and I came across a discarded headlight. I looked at it closely (it had one of the convex glass lenses that we've previously covered in this column, so I was already interested) and then I saw a silver box attached to the outside of the assembly, right next to a warning about very high voltages. It was then I guessed it was an HID unit and snaffled it.

Disassembly and wiring

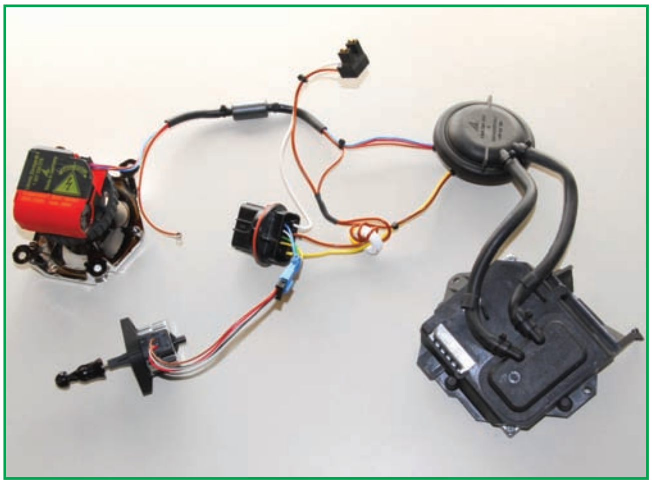
If you haven't recently looked inside a modern headlight – let alone an HID design – it can all be pretty baffling. The socket on the plastic housing may have as many as eight connections, the optical assembly may have up to three bulbs, and there are likely to be two separate reflectors and potentially also a glass convex lens present in the assembly.

The first step is to mentally split the system into three light sources – high beam, low beam and parking lights. These are likely to all use different bulbs, reflectors and (possibly) lenses.

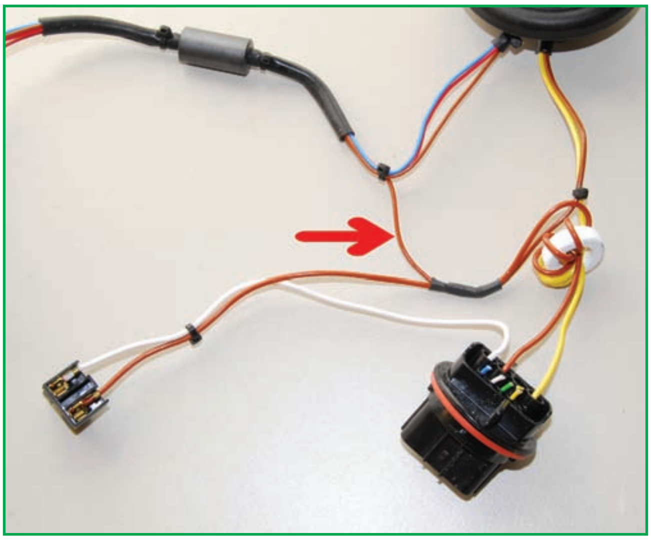


This alloy box on the side of the headlight assembly is a strong indication that it is an HID light...

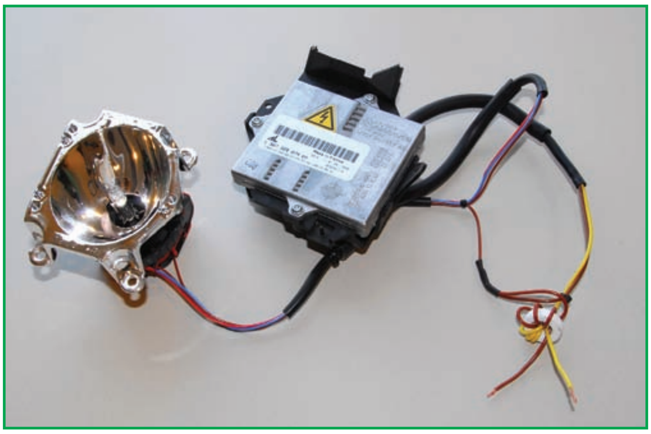
...and this high voltage warning sticker confirms it



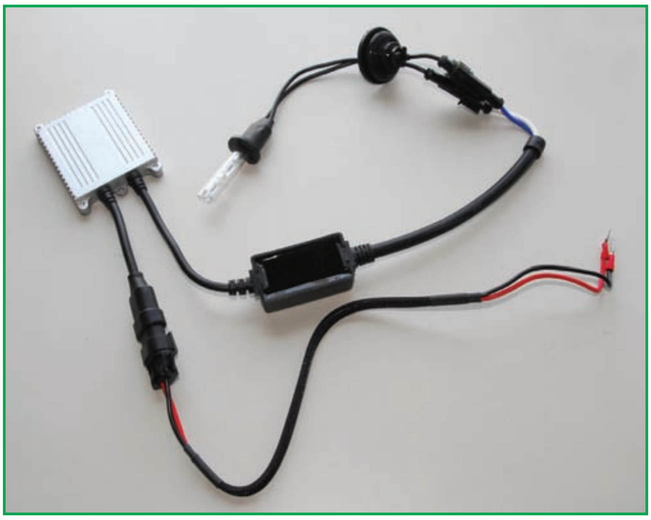
The lights and wiring removed from the housing. From left top and then clockwise: low beam HID light, reflector and second part of HID ballast; high beam plug; waterproof cover; first part of HID ballast; beam level adjustment actuator. In the centre is the wiring socket



With the beam levelling actuator wiring snipped off, it can be seen that the high beam plug (lower left) and the HID wiring share a common brown wire (arrowed) – the ground wire



This shows the high beam socket and wiring removed. The remaining two wires are yellow for +12V and brown for ground. When 12V was connected to these wires, the light came to life. Note that very high voltages are present on most of the pictured wiring – you must not touch anything when the light is running!



If you cannot find a salvageable secondhand or discarded HID light, you may want to buy a new 'bulb upgrade' HID system like this one. Disadvantages are the higher cost and the need to mount the bulb, but availability is as close as your credit card.

The next step is to see if there's any beam levelling system present – most HID lights have the capacity to adjust beam angle so as not to blind oncoming drivers when the rear of the car is laden. The ground connection on all the light sources is likely to be shared.

Finally, HID lighting is likely to be used for only the low beam – the high beam and parking lights are typically conventional incandescent. (But if you're reading this a few years after it was written, look for LEDs as the parking lights and also daytime visibility lights!)

This may sound confusing, but if you can sort out which systems are which, understanding the wiring becomes much more straightforward.

In the headlight I salvaged (I think it may have been from a new shape Mini), things were considerably simplified by extracting the headlight assembly from the housing, and removing the high beam bulb, the associated wiring and the low beam levelling motor (there was no parking light). In fact, that left only two power supply wires to the HID ballast – brown and yellow.

The brown wire was also shared with the (now snipped off) high beam wiring, so that implied it was a ground wire. Connecting positive 12V to the yellow wire and ground to the brown wire (and then standing clear before switch-on) brought the light to immediate life.

Lenses and reflectors

As with any light source, using lenses and reflectors will improve the beam intensity and light distribution. If you want a beam distribution much like a car headlight, and the parts are still available, you can use the optics of the original assembly.

However, be aware that these optics probably include a shield that blanks off the upper portion of the low beam. This shield may or may not be easily removable. The lens or reflector in a salvaged headlight may also be broken, and if you've sourced a new HID upgrade kit, no reflector or lens will be included.

In short, the reflector and lens that you use depends on availability and the application of the light. Note that a new HID upgrade kit will need something to hold the bulb in place – easiest is to source an original headlight that suits the bulb type (eg H1 or H3) and then to use that with the HID bulb, either with the headlight completely intact or suitably modified.

Mounting

The light must be mounted so that the ballast is well ventilated, that it is impossible for people to come into contact with any of the wiring, and that combustible items are not heated by the high-power lamp.

Conclusion

When working with HID lights you must always remember the high voltages that the system is operating at – it's harder than you think to keep this in mind because after all, 'it's just a car headlight'. But with this aspect kept in mind, salvaged automotive HID lighting can provide brilliant, efficient lighting – especially when you have only a low voltage DC source available.

Rat It Before You Chuck It!

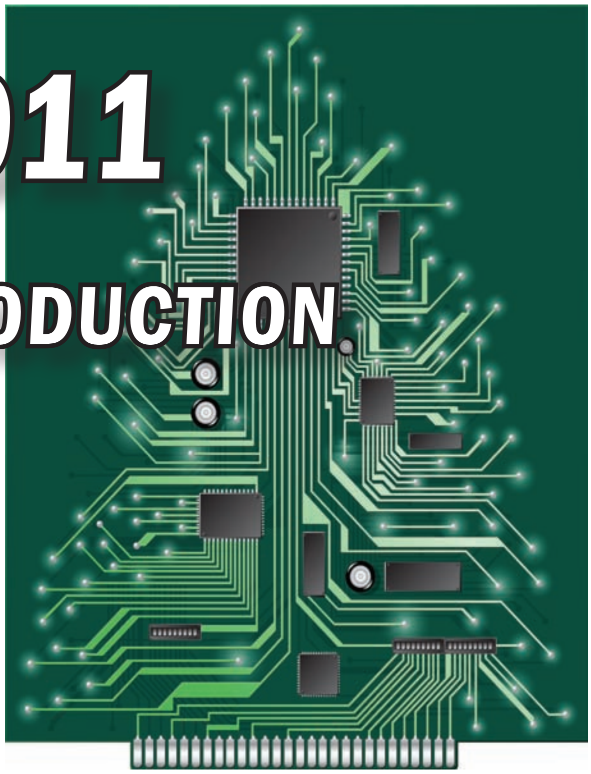
Whenever you throw away an old TV (or VCR or washing machine or dishwasher or printer) do you always think that surely there must be some good salvageable components inside? Well, this column is for you! (And it's also for people without a lot of dough.) Each month we'll use bits and pieces sourced from discards, sometimes in mini-projects and other times as an ideas smorgasbord.

And you can contribute as well. If you have a use for specific parts which can easily be salvaged from goods commonly being thrown away, we'd love to hear from you. Perhaps you use the pressure switch from a washing machine to control a pump. Or maybe you have a use for the high-quality bearings from VCR heads. Or perhaps you've found how the guts of a cassette player can be easily turned into a metal detector. (Well, we made the last one up, but you get the idea . . .)

So, if you have some practical ideas, do write in and tell us!

TEACH-IN 2011

A BROAD-BASED INTRODUCTION TO ELECTRONICS



Part 2: Resistors, capacitors, timing and delay circuits

By Mike and Richard Tooley

Our Teach-In series is designed to provide you with a broad-based introduction to electronics. We have attempted to provide coverage of three of the most important electronics units that are currently studied in many schools and colleges in the UK. These include Edexcel BTEC Level 2 awards, as well as electronics units of the new Diploma in Engineering (also at Level 2). The series will also provide the more experienced reader with an opportunity to 'brush up' on specific topics with which he or she may be less familiar.

Each part of our Teach-In series is organised under five main headings: *Learn*, *Check*, *Build*, *Investigate* and *Amaze*. Learn will teach you the theory, Check will help you to check your understanding, and Build will give you an opportunity to build and test simple electronic circuits. Investigate will provide you with a challenge which will allow you to further extend your learning, and finally Amaze will show you the 'wow factor'!

In last month's instalment, Learn provided you with an introduction to the signals that convey information in electronic circuits and the units, multiples and sub-multiples that are used when measuring electrical quantities. Build featured an introduction to Circuit Wizard, showing you how to install the software and use a virtual test instrument while our practical sections, Investigate and Amaze, provided you with an opportunity to get to grips with an oscilloscope based on a PC soundcard.

IN this part of Teach-In 2011 we will introduce you to resistors, capacitors, timing and delay circuits. We will also use Circuit Wizard to investigate Ohm's Law as well as finding out what happens in a circuit when a capacitor is charged and discharged.

Learn

Resistors

From last month's Teach-In, you should recall that voltage is specified in volts (V), current in amps (A) and resistance in ohms (Ω). A potential difference of 1V will appear across a resistance of 1Ω when a current of 1A flows in it.

Resistance can be thought of as an opposition to the flow of electric current. The amount of current that will flow in a circuit when a given electromotive force (EMF) is applied to it is inversely proportional to its resistance. In other words, the larger the resistance, the greater the opposition to current flow when an EMF is applied.

Ohm's law

Ohm's law tells us that the relationship between voltage, V, current, I, and resistance, R, in a circuit (see Fig.2.1) is:

$$V = I \times R$$

where V is the voltage (in V), I is the current (in A) and R is the resistance (in Ω).

Example 1

A current of 200mA flows in a 50Ω resistor. What potential difference appears across the resistor?

From Ohm's Law:

$$V = I \times R = 0.2 \times 50 = 10\text{V}$$

(Note that 200mA is the same as 0.2A)

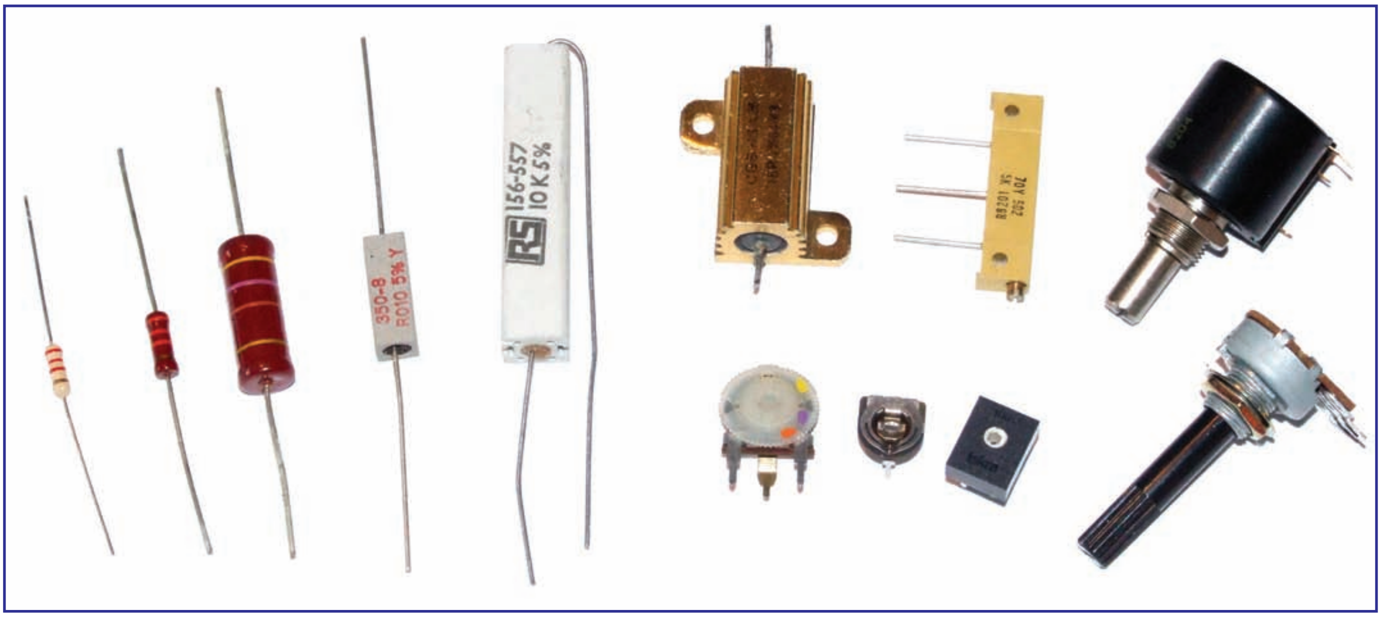


Fig.2.2. Various types of resistor, including fixed, preset and variable types

Example 2

What current will flow when a 22Ω resistor is connected to a 12V battery?

Rearranging the formula to make *I* the subject gives:

$$I = \frac{V}{R} = \frac{12}{22} = 0.545\,\text{A} = 545\,\text{mA}$$

Example 3

A current of 15mA flows in a resistor when it is connected to a 24V power supply. What is the value of the resistance?

Rearranging the formula to make *R* the subject gives:

$$R = \frac{V}{I} = \frac{24}{0.015} = 1600\,\Omega = 1.6\,\text{k}\Omega$$

(Note that 15mA is the same as 0.015A)

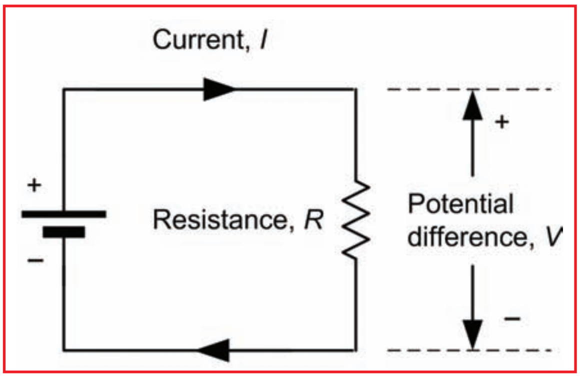


Fig.2.1. A simple circuit in which a battery supplies current to a resistor

Types of resistor

Various types of fixed, preset and variable resistor are found in electronic circuits, including carbon film, metal film, and wirewound types, see Fig.2.2. Resistors have a wide variety of applications in electronic circuits, where they are used for determining the voltages and currents in circuits, as 'loads' to consume power, and in preset and variable form for making adjustments (for example, volume and tone controls).

The terms **potentiometer** and variable resistor are often used interchangeably. However, strictly speaking, preset and variable resistors have only two terminals while potentiometers (either preset or rotary types) have three terminals. Note also that a preset or variable potentiometer can be used as a variable resistor by simply ignoring one of its end terminals, or by connecting its moving contact to one of its outer terminals. Typical circuit symbols for various types of resistor are shown in Fig.2.3.

The specifications for a resistor usually include the value of resistance (expressed in Ω, kΩ or MΩ), the accuracy or **tolerance** of the marked value (quoted as the maximum permissible percentage deviation from the marked

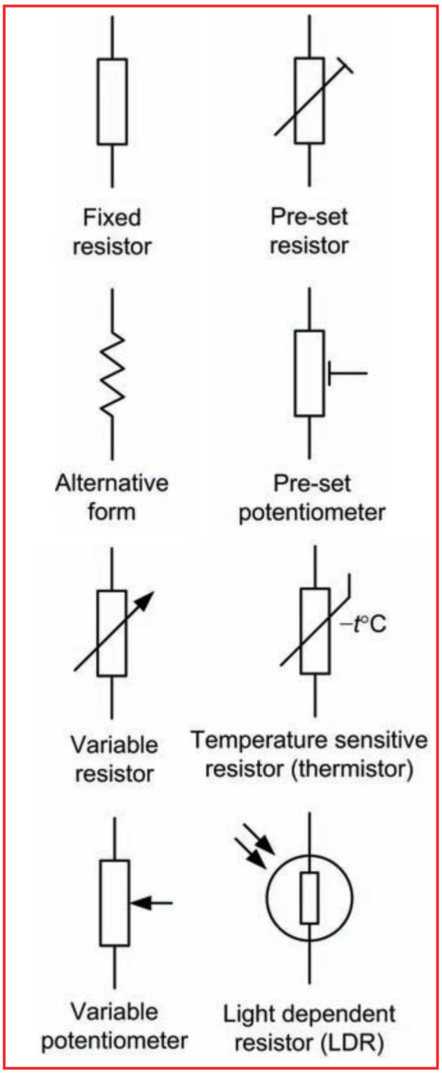


Fig.2.3. Circuit symbols used for resistors

value), and the power rating (which must be equal to, or greater than, the maximum expected power dissipation).

Fixed resistors

Fixed resistors are available in several series of 'preferred' values, see Table 2.1. The number of values provided with each series (ie 6, 12 and 24) is determined by the tolerance involved.

In order to cover the full range of resistance values using resistors having a ±20% tolerance, it is necessary to provide six basic values (known as the E6 series). More values are required in a series that offers a tolerance of ±10%, and consequently the E12 series provides twelve basic values.

The E24 series for resistors of ±5% tolerance provides 24 basic values and, as with the E6 and E12 series, decade multiples (ie, ×1, ×10, ×100, ×1k, ×10k, ×100k and ×1M) of the basic series. A further series (E48) provides for resistors with a tolerance of ±2%.

Carbon and metal oxide resistors are normally marked with colour codes that indicate their value and tolerance. See Fig.2.4 and Fig.2.5 for the colour codes.

Table 2.1: The E6, E12 and E24 series of preferred resistor values

Series of preferred values	*Values available*
E6	1.0, 1.5, 2.2, 3.3, 4.7, 6.8
E12	1.0, 1.2, 1.5, 1.8, 2.2, 2.7, 3.3, 3.9, 4.7, 5.6, 6.8, 8.2
E24	1.0, 1.1, 1.2, 1.3, 1.5, 1.6, 1.8, 2.0, 2.2, 2.4, 2.7, 3.0, 3.3, 3.6, 3.9, 4.3, 4.7, 5.1, 5.6, 6.2, 6.8, 7.5, 8.2, 9.1

Relationship between voltage, current and power

The power, P, dissipated in a resistor is equivalent to the product of voltage, V, and current, I. Thus:

$$P = IV$$

where P is the power (in W), I is the current (in A) and V is the voltage (in V).

We can combine this relationship with the Ohm's law equation that we met earlier in order to arrive at the following useful expressions:

$$P = IV = I \times (IR) = I^2 R$$

and

$$P = IV = \frac{V}{R} \times V = \frac{V^2}{R}$$

Example 4

What power is dissipated in a resistor of 1kΩ when a voltage of 20V appears across it?

Using the previous formula gives:

$$P = \frac{V^2}{R} = \frac{20^2}{1000} = \frac{400}{1000} =$$

$$= 0.4\text{W}$$

Fig.2.4. Four-band resistor colour code

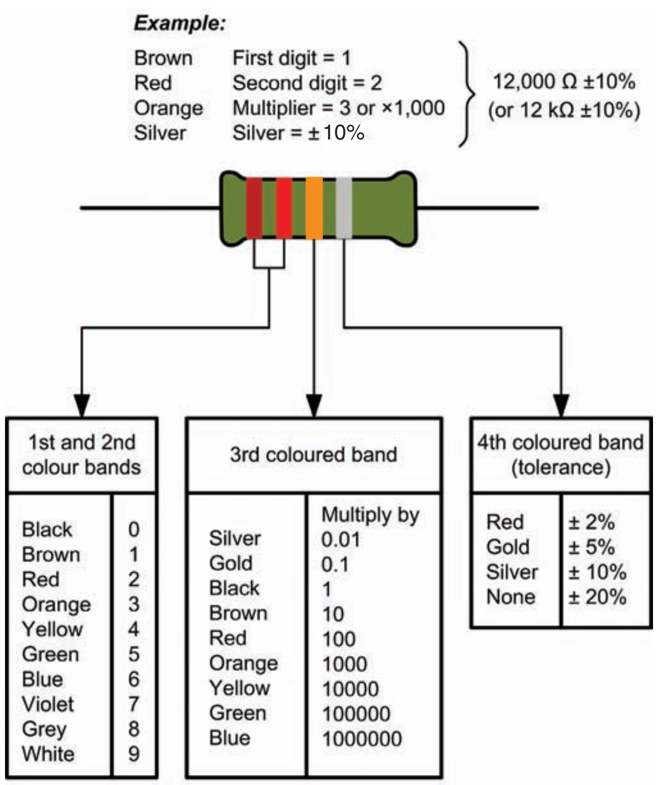
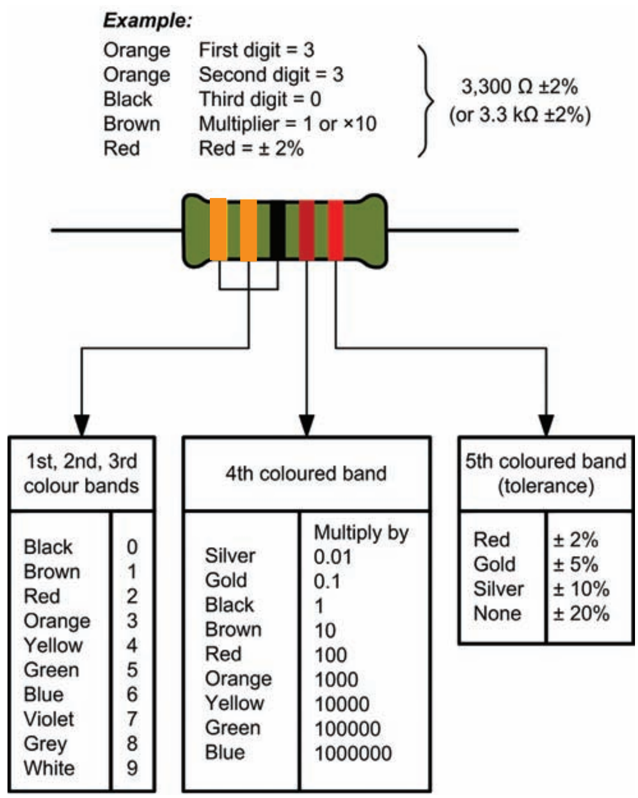


Fig.2.5. Five-band resistor colour code



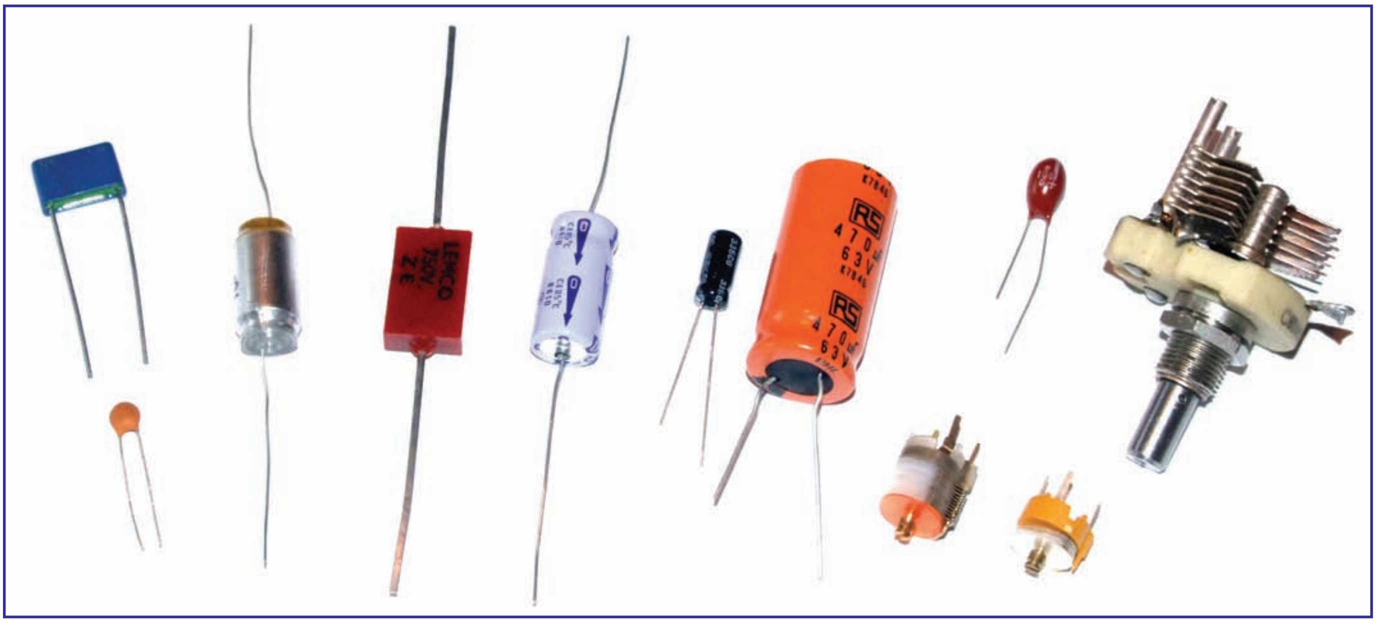


Fig.2.7. Various types of capacitor, including fixed, preset and variable types

Capacitors

Capacitors store energy in the form of an electric field. When a potential difference is applied to two conducting plates an electric charge will appear on the plates and an electric field will appear between the plates. The field can be concentrated/intensified by placing an insulating material (such as polyester film, mica or a ceramic material) between the plates. This material is known as a **dielectric,** and its electrical properties help to increase the **capacitance** of the component (see Fig.2.6).

Capacitors provide us with a means of storing and conserving electric charge. They are widely used in power supplies where they act as 'reservoirs' for charge and also in many timing and wave-shaping circuits. Capacitors will pass alternating currents, but they will 'block' direct current (once charged). They are thus used for coupling signals (which are AC) in and out of amplifier stages.

The specifications for a capacitor usually include the value of capacitance (expressed in F, µF, nF or pF), the accuracy or tolerance of the marked value (quoted as the maximum permissible percentage deviation from the marked value), the voltage rating (which must be equal to, or greater than, the maximum expected voltage applied to the capacitor). Capacitors are usually available with values in the E6 series (see Table 2.1).

Please note!

Large value capacitors often use a chemical dielectric material, and they require the application of a DC **polarising voltage** in order to work

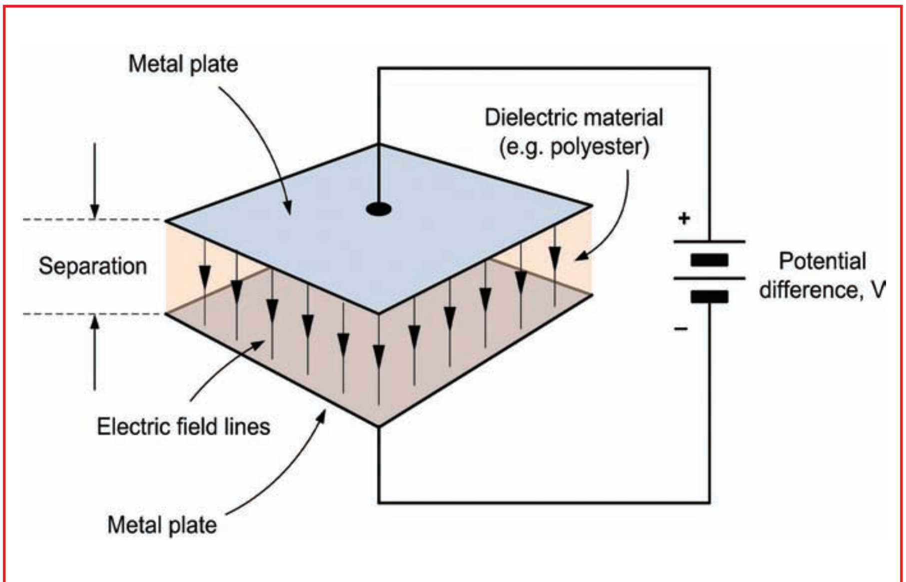


Fig.2.6. Basic arrangement of a parallel plate capacitor

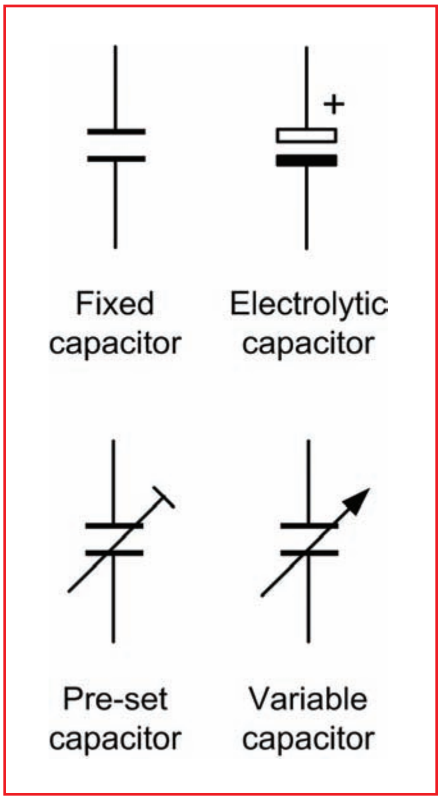


Fig.2.8. Symbols used for capacitors

properly. This voltage must be applied with the correct polarity (invariably this is clearly marked on the case of the capacitor) with a positive (+) sign or negative (–) sign or a coloured stripe or other marking. Failure to observe the correct polarity can result in overheating, leakage, and even a risk of explosion!

Relationship between charge, voltage and capacitance

The quantity of electric charge, *Q*, that can be stored in the electric field between the capacitor plates is proportional to the applied voltage, *V*, and the capacitance, *C*, of the capacitor.

Thus:

$$Q = C\,V$$

where *Q* is the charge (in coulombs), *C* is the capacitance (in farads), and *V* is the potential difference (in volts).

Example 5

Determine the charge stored in a 10µF capacitor when it is charged to a potential of 250V.

The charge stored will be given by:

$$Q = C\,V = 10 \times 10^{-6} \times 250$$
$$= 2500 \times 10^{-6} = 2.5 \times 10^{-3}$$
$$= 2.5\text{mC}$$

Energy storage

A charged capacitor acts as a reservoir for charge and the stored energy can be put to good use some time later. The amount of energy stored in a capacitor depends on the product of capacitance, *C*, and the square of the applied voltage, *V*. Thus, to store a large amount of energy we need a correspondingly larger value of capacitance for a given value of charging voltage. The following relationship applies:

$$W = \tfrac{1}{2}\,C\,V^2$$

where *C* is the value of capacitance (in F), *V* is the capacitor voltage, and *W* is the stored energy (in joules).

Example 6

Determine the charge stored in a 220µF capacitor when it is charged to a potential of 50V.

The stored energy will be given by:

$$W = \tfrac{1}{2}\,C\,V^2 = \tfrac{1}{2} \times 220 \times 10^{-6}$$
$$\times\, 50^2 = 110 \times 2500 \times 10^{-6}$$
$$= 0.275\text{J}$$

Please note!

The energy stored in a capacitor is proportional to the square of the potential difference between its plates. Thus, if the potential difference is doubled the energy stored will increase by a factor of four. Likewise, if the potential difference increases by a factor of ten, the stored energy will increase by a factor of 100.

Please note!

A charged capacitor can remain in a partially charged state for a very long time if there is no path for the stored charge to drain away. It's therefore important to avoid working on a circuit that uses large value capacitors (particularly if they are high-voltage types) until you are certain that the capacitors are fully discharged. Some circuits incorporate 'bleed' resistors to safely discharge large value capacitors when the equipment in which they are used has been switched off.

C-R circuits (charge and discharge)

Earlier, we mentioned that a capacitor is a device for storing electric charge. This charge can be stored in a capacitor by connecting it to a battery or power supply via a series resistor, which supplies current for charging. Later, the stored charge can be drained away by connecting a resistor in parallel with the capacitor. After a period of time there will then be no charge remaining in the capacitor.

The time that it takes to charge and discharge a capacitor depends on the values of capacitance and resistance, and this makes capacitors ideal for use in timing and delay circuits. Because this is so important, it's worth looking at this in a little more detail.

Simple charging and discharging arrangements are shown in Fig.2.9. In the charging arrangement shown in Fig.2.9a, the capacitor is initially uncharged and current will flow and charge will build up inside the capacitor, quickly at first and then more slowly.

As the capacitor becomes charged, the capacitor voltage (V_C) will increase until it eventually becomes close, but never quite equal, to the voltage of the supply (V_S). At that point (when V_C is approximately equal to V_S) we say that the capacitor is fully charged.

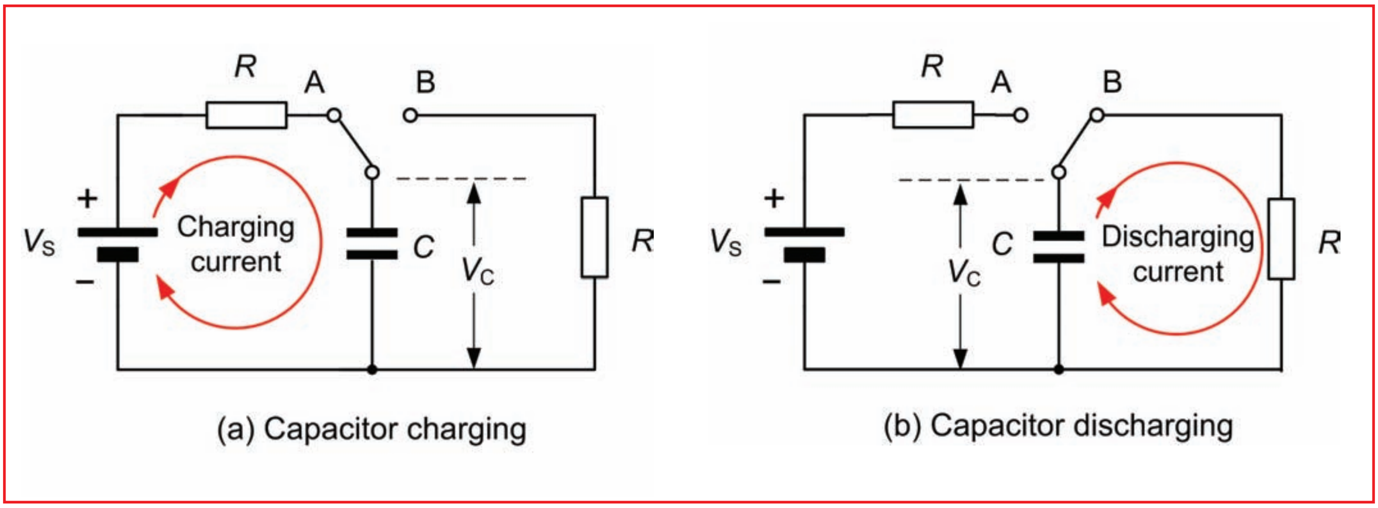


Fig.2.9. A capacitor charging/discharging arrangement

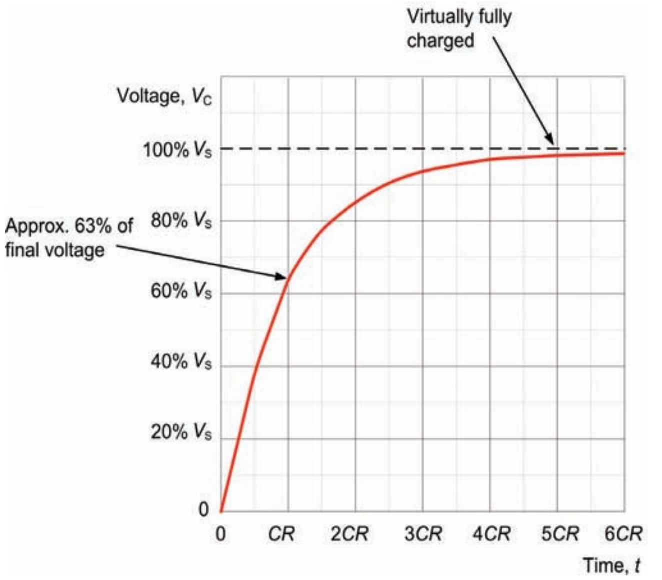


Fig.2.10. Graph of capacitor voltage against time for the charging circuit

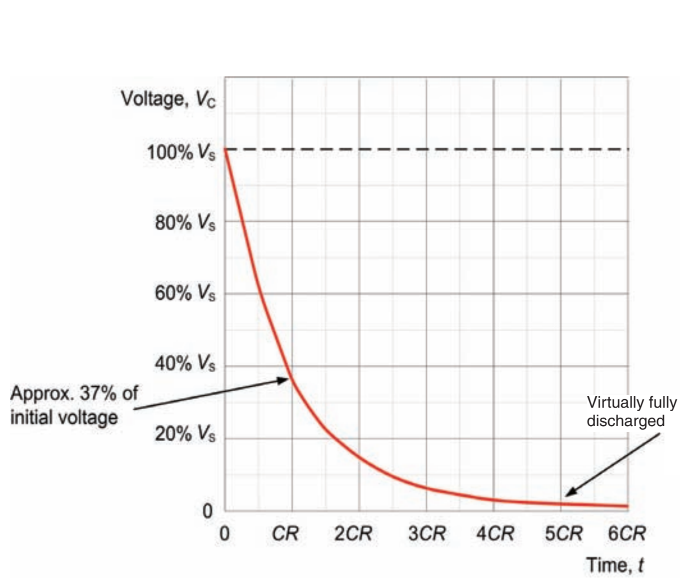


Fig.2.11. Graph of capacitor voltage against time for the discharging circuit

A graph showing how the capacitor voltage (V_C) increases with time is shown in Fig.2.10. This graph is known as an **exponential growth** curve.

The speed at which the capacitor becomes charged depends on the **time constant**, T, of the circuit. This is the product of the capacitance, C, and the charging resistance, R. Hence:

$T = C \times R$

where C is the value of capacitance (in F), R is the resistance (in Ω), and T is the time constant (in seconds).

You might now be wondering how long it takes to *fully* charge the capacitor? The true answer is that the capacitor voltage never quite reaches the supply voltage, even if you wait for a *very* long time. However, it does get closer and closer to it, and for this reason we say that the capacitor is fully charged after a time interval equal to five times the time constant ($5T$ or $5CR$).

In the discharging arrangement shown in Fig.2.9b, the capacitor is initially fully charged and current will flow while the charge inside the capacitor decays away. As the capacitor becomes discharged, the capacitor voltage (V_C) will decrease until it eventually becomes close, but never quite equal, to zero (0V). At that point (when V_C is approximately equal to 0V), we say that the capacitor is fully discharged. A graph showing how the capacitor voltage (V_C) decreases with time is shown in Fig.2.11. This graph is known as an **exponential decay** curve.

Once again, the speed at which the capacitor becomes discharged depends on the **time constant**, T, of the circuit. For our discharging circuit the time constant is also given by

$T = C \times R$

As before, you might now be wondering how long it takes to *fully* discharge the capacitor? The true answer is that the capacitor voltage never quite reaches 0V, even if you wait for a very long time. However, it does get closer and closer to 0V, and for this reason we say that the capacitor is fully discharged after a time interval equal to five times the time constant ($5T$ or $5CR$).

Example 7

A C-R circuit consists of C = 2.2µF and R = 1.5 MΩ.

(a) What is the time constant of the circuit?

(b) If the capacitor is initially uncharged, how long will it take to fully charge the capacitor?

(a) The time constant is given by:

$T = CR = 2.2\mu F \times 1.5M\Omega = 3.3$ seconds

(Note that if we work in µF and MΩ the time constant will be expressed directly in seconds)

(b) The capacitor will be approximately fully charged after $5T$ or 5×3.3 or 16.5 seconds.

Please note!

The voltage across the plates of a charging capacitor grows exponentially (not linearly!) at a rate determined by the time constant of the circuit. Conversely, the voltage across the plates of a discharging capacitor decays exponentially (not linearly!) at a rate determined by the time constant of the circuit

Circuit Wizard

A *Standard* or *Professional* version of Circuit Wizard can be purchased from the editorial office of *EPE* – see *CD-ROMs for Electronics* page and the UK shop on our website (**www.epemag.com**) for a 'special offer'.

Further information can be found on the New Wave Concepts website; **www.new-wave-concepts.com**. The developer also offers an evaluation copy of the software that will operate for 30 days, although it does have some limitations applied, such as only being able to simulate the included sample circuits and no ability to save your creations, this is the software that is free with *EPE* this month.

However, if you're serious about electronics and want to follow our series, then a full copy of Circuit Wizard is a really sound investment.

Check – How do you think you are doing?

1. Explain briefly what is meant by resistance. What units are used for resistance and what symbol is used to denote these units?

2. Explain briefly what is meant by capacitance. What units are used for capacitance and what symbol is used to denote these units?

3. A current of 0.5A flows in a 22Ω resistor. What potential difference appears across the resistor?

4. What current will flow when a 15Ω resistor is connected to a 6V battery?

5. A current of 75mA flows in a resistor when it is connected to a 15V power supply. What is the value of the resistance?

9. A charge of 11µC is held in a 220nF capacitor. What potential appears across the plates of the capacitor?

10. A charge of 350µC is to be placed on the plates of a capacitor of 470nF. What voltage is needed to do this

11. A resistance of 100kΩ is connected to a capacitor of 47µF. What is the time constant of this circuit and how long will it take for the capacitor to become approximately fully charged?

12. What components are represented by the circuit symbols shown in Fig.2.12?

13. What type of component is shown in Fig.2.13?

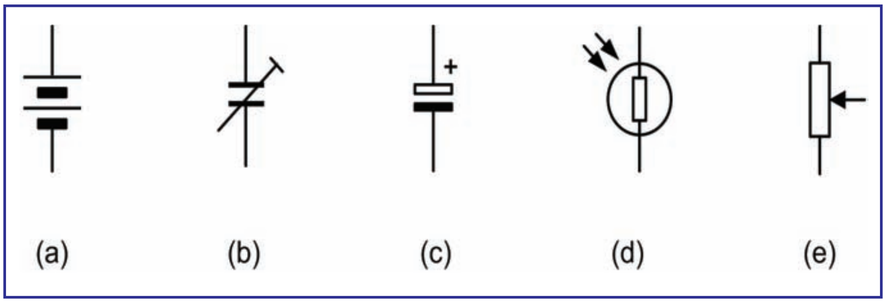


Fig.2.12. See question 12

6. A voltage drop of 12V appears across a 60Ω resistor. What power is dissipated in the resistor?

7. A resistor is rated at 100Ω, 0.25W. What is the maximum voltage that can be safely applied to this resistor?

8. A 220µF capacitor is charged to a potential of 30V. What charge is present?

14. A resistor is marked with the following coloured bands: brown, black, orange, silver. What is the value of the resistor and what is its tolerance?

15. A resistor of 205Ω at ±2% is required. What should be the colour code for this component?

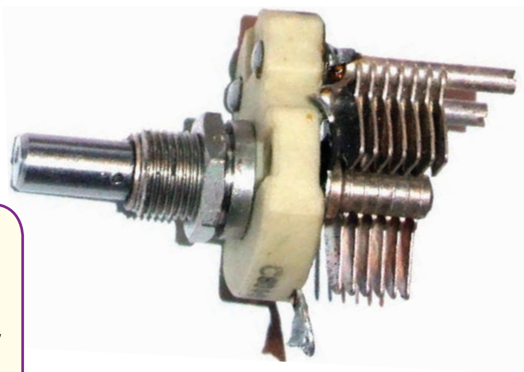


Fig.2.13. See question 13

For more information, links and other resources please check out our Teach-In website at:
www.tooley.co.uk/teach-in

Build –

IN THIS month's 'Learn' section we've introduced you to the basics of resistors and capacitors. Almost all electronic circuits will contain one or both of these types of components, so it's really important that we understand what they do and how they work.

Electronics text books often have lengthy and confusing explanations with lots of mathematical formulae. However, the best way to really get to grips with what's going on is to experiment with some simple circuits. We are going to look at a few of the sample circuits included with Circuit Wizard, as well as giving you some new circuits to enter and try out for yourself.

Ohm's Law in practice

To start with, we'll have a look at Ohm's Law in practice. Open the 'Ohm's Law' sample circuit from the Assistant panel on the right-hand side of the screen by selecting 'Sample Circuits', then 'Elementary Circuits' and scrolling down to the 'Electrical Theory' section.

The circuit (see Fig.2.14) is about as simple as it comes with a power source (a 9V PP3 battery) and a variable resistor. We also have two multimeters; one to show the voltage across the resistor and one to show the current flowing through it.

Simulation

Press the play button (found on the toolbar) to activate the simulation. You should see values appearing on the multimeters.

Now try changing the value of the variable resistor (VR1) by clicking on the end of the shaft – the mouse pointer will change to a pointed finger when you're in the right place. You'll then be presented with a virtual knob that you can turn to the desired value.

Notice that as you increase the resistance, the current flowing through it reduces and *vice versa*. Note that the readings for current are in milliamps (mA).

To try out the theory that we introduced, check the values for voltage and current when the variable resistor is at 50, 250, 500, 750 and 1k, and check that they obey Ohm's law.

The Circuit Wizard way

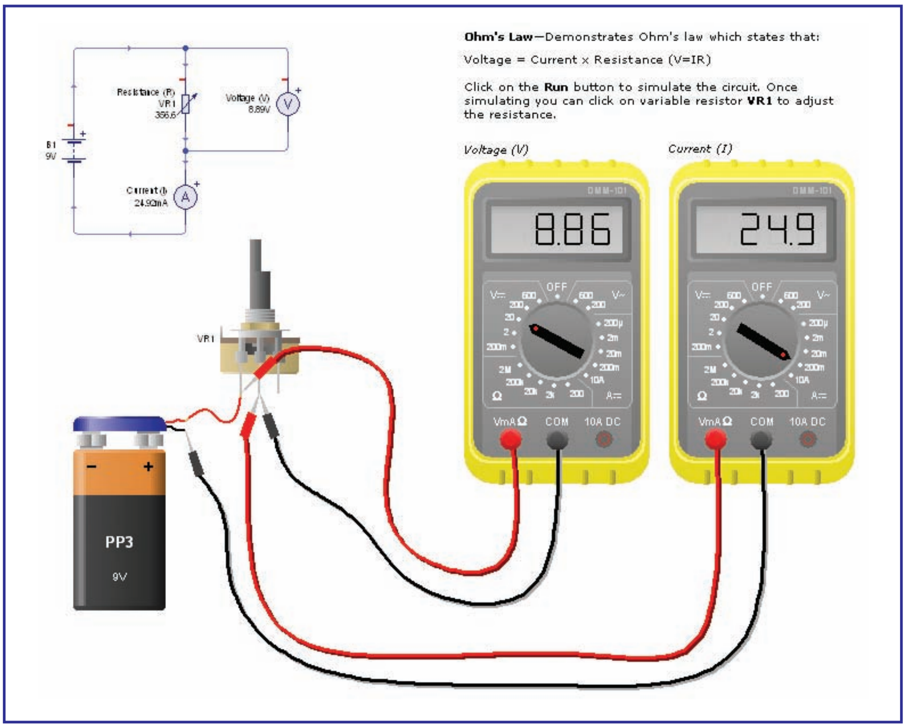


Fig.2.14. The Ohm's Law sample circuit

Capacitors in action

Now we'll take a look at capacitors in action. Open 'Capacitor Charging' by selecting Sample Circuits, then Basic Circuits in the Assistant (see Fig.2.15). When the file opens it will start off in 'PCB Layout' view, which shows a virtual representation of the circuit, along with an oscilloscope showing the voltage across a 100µF capacitor (C1).

Start simulating the circuit and keep an eye on the 'dot' on the oscilloscope screen. Watch how it rises as the capacitor charges. Once the trace has levelled off, flick the switch to start discharging the capacitor and again watch the oscilloscope screen to see how the voltage falls with time.

Circuit diagram

To see the schematic layout for the circuit, switch to the 'Circuit Diagram' view using the tabs on the bottom of the screen. Start the simulation again and control the switch to allow the capacitor to charge and discharge.

The voltage across the capacitor is then plotted on the graph in real time. Circuit Wizard also demonstrates the charge building up on the plates of the capacitor with blue/red 'plusses' and 'minuses'.

In 'Learn' we showed how to calculate the time period using the formula $T = CR$, which is when the voltage across the capacitor has reached 63% of the supply voltage (around 5.7V in this case). Once you have a nice looking plot for charging and discharging, print out your graph (see Fig 2.16).

Calculate the time constant for the circuit (using the values of C and R) and then, using a ruler, draw a vertical line up from that value on the graph (from the point at which it started to charge) and read off the voltage at this point. Does it agree with what you would expect?

The last sample circuit that we'll look at is a practical application of charging a capacitor. Open 'Transistor Timer' from 'Sample Circuits' (found under 'Basic Circuits', 'General'). The circuit uses a capacitor to create a time delay before the bulb is illuminated. It does this by using a pair of transistors acting like a switch. We'll be looking at transistors in more detail in subsequent Teach-In editions.

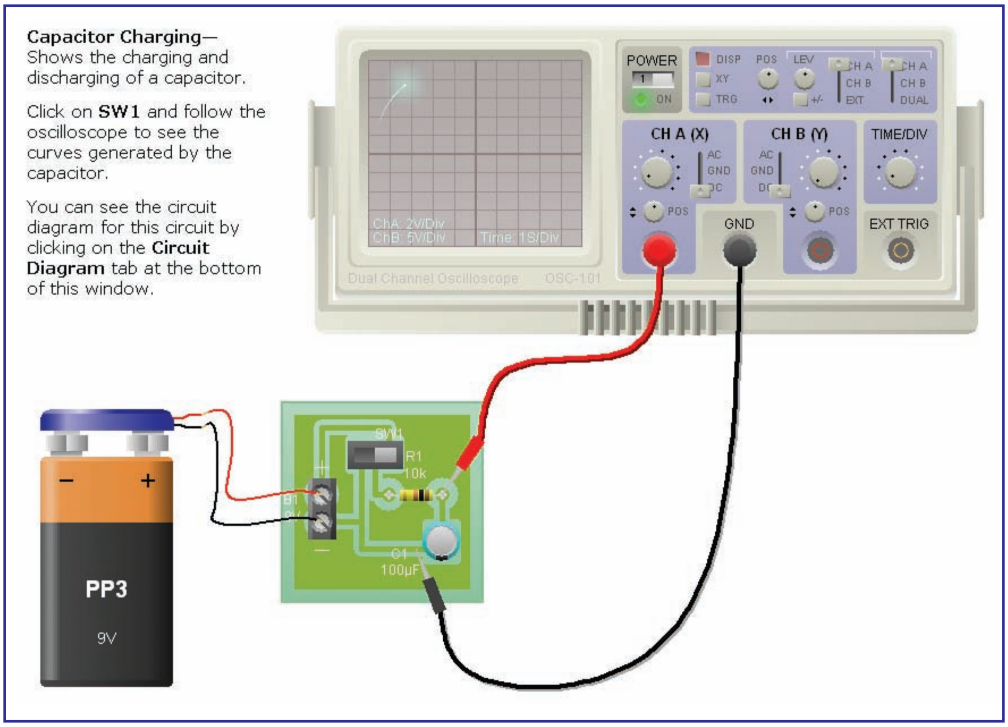


Fig.2.15. The capacitor-charging sample circuit

The Circuit Wizard way

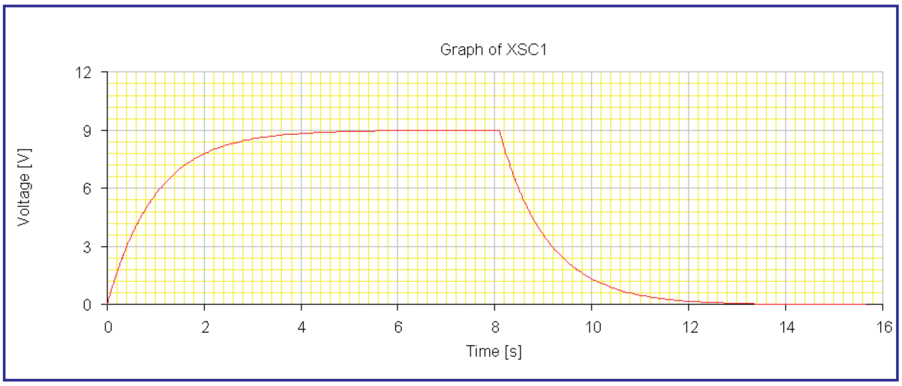


Fig.2.16. Graph of capacitor voltage plotted against time, which shows first charge and then discharge

Start the simulation and test the circuit's operation. As the capacitor charges the voltage across it increases. Once the voltage reaches a certain value the transistors 'turn on', allowing current to flow from the positive of the battery through the bulb to ground (0V) and therefore lighting it.

The longer it takes for the capacitor to charge, the longer the delay will be before the bulb lights. The capacitor charges through the variable resistor (VR1). Therefore, by changing the value of the resistor we can change how fast the capacitor charges and hence set the delay. It's a bit like turning a tap to change how fast you fill up a bucket of water. Try setting the variable resistor so that there is a two-second delay before the bulb lights.

Amaze

Capacitors normally come in very small values. For example a 10pF capacitor has a value of 0.00000000001 farads – that's a pretty small number! In fact, a one farad capacitor is enormous relatively speaking.

What's the largest value capacitor that you can find? Try looking at how capacitors are used in some of the most elaborate car audio systems, as they can be very big!

Fig.2.17. A selection of capacitors that provide some extremely large values of capacitance!

Investigate

The data shown in Table 2.2 was obtained during an experiment on a *C-R* circuit. Use this data to plot a graph showing how the capacitor voltage varies with time and then use the graph to answer the following questions:

1. Is the capacitor being charged or discharged?

2. From the graph, estimate the time constant of the *C-R* circuit. (Hint: Take a look at Fig.2.11!)

3. If the value of *R* is 1MΩ, determine the value of *C*.

4. How much energy is stored in the capacitor at the start of the experiment and where does this energy go?

Table 2.2: Table of results for the experimental *C-R* circuit

Time (s)	0	5	10	15	20	25	30
Capacitor Voltage (V)	15.0	7.4	3.6	1.8	0.9	0.4	0.2

Answers to Questions

1. See page 50, Ohm, Ω

2. See page 53, Farad, F

3. 11V

4. 0.4A

5. 200Ω

6. 2.4W

7. 5V

8. 6.6mC

9. 50V

10. 745V

11. 4.7s, 23.5s

12. (a) battery, (b) preset capacitor, (c) electrolytic capacitor, (d) light dependent resistor (LDR), (e) variable potentiometer

13. Variable capacitor

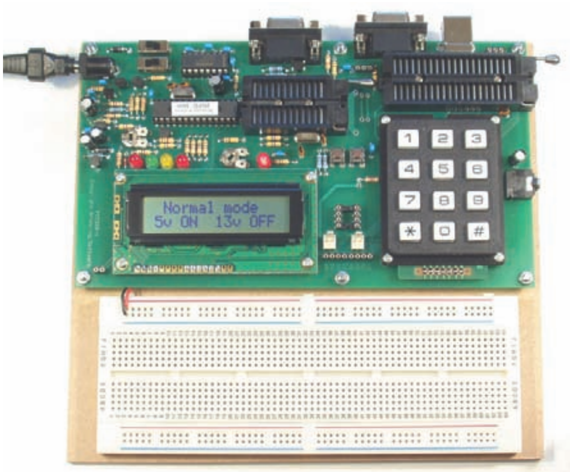
14. 10kΩ, ±10%

15. Red, black, green, black, red

Next month!

In next month's Teach-In we shall be looking at diodes and power supplies.

PIC Training Course



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Experimenting with PIC Microcontrollers

This book introduces PIC programming by jumping straight in with four easy experiments. The first is explained over seven pages assuming no starting knowledge of PICs. Then having gained some experience we study the basic principles of PIC programming, learn about the 8 bit timer, how to drive the liquid crystal display, create a real time clock, experiment with the watchdog timer, sleep mode, beeps and music, including a rendition of Beethoven's *Fur Elise*. Then there are two projects to work through, using a PIC as a sinewave generator, and monitoring the power taken by domestic appliances. Then we adapt the experiments to use the PIC18F2321. In the space of 24 experiments, two projects and 56 exercises we work through from absolute beginner to experienced engineer level using the very latest PICs.

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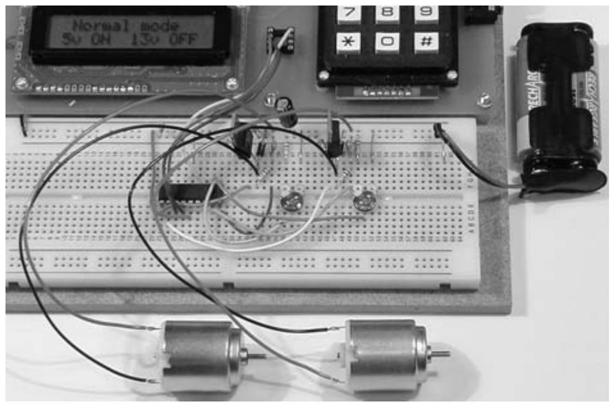
Telephone with Visa, MasterCard or Switch, or send cheque/PO. All prices include VAT if applicable.



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Using LTspice to display useful spectra

LAST month, we looked at the some of the concepts behind spectral analysis in response to the following question from frequent *EPE Chat Zone* contributor ***741***.

On LTspice I placed an ideal sine generator, then chose View/FFT. I noticed the wide 'skirts' leading up to the peak at the sine frequency. I wondered what determines the sharpness of the peak.

This month we will look more specifically at the how to use LTspice to display useful spectra. A spectrum is a graph which shows the contributions of different frequencies to a signal. All waveforms, apart from pure sinewaves, comprise several frequencies; with complex waveforms such as voice signals containing a wide range of different frequencies.

Looking at the spectrum of a signal can provide useful information about the signal itself, or the circuitry from which it was measured. For example, a spectrum can be used to find the total harmonic distortion (THD) introduced to a sinewave by an amplifier – we discussed THD in detail in a recent couple of articles.

Fourier series

The fundamental mathematics behind the spectrum is the Fourier series, which represents any periodic waveform as a weighted sum of sinewaves at multiples of the fundamental frequency. As we discussed last month, this must be extended to the Fourier transform to handle non-periodic signals, such as voice waveforms.

To implement a spectrum analyser – as an instrument, or in software – we have to work with a finite number of samples of the waveform of interest. This requires use of the discrete Fourier transform (DFT). The DFT can be implemented in hardware or software in a number of different ways; however, the most common approach is the fast Fourier transform, which was mentioned by 741.

The FFT makes particularly efficient use of hardware or computing resources, hence it is very fast, as the name suggests. Usually, the FFT requires that the number of waveform samples used is a power of two, but this is generally not a difficult restriction.

A touch of spice

The circuit in Fig.1, which we introduced last month, is all you need to get LTspice to display a spectrum. The voltage source produces a 1V, 1kHz sinewave, which is applied to a 1kΩ resistor. A transient simulation is run for 5ms, which will cover five cycles of the sinewave.

For the benefit of readers who may not be fully familiar with LTspice, the following paragraphs describe how to draw the schematic shown in Fig.1 and run a simulation. After that we will discuss use of the FFT function.

If you do not have LTspice, it is free software which can be downloaded from the Linear Technology website, **www.linear.com/designtools/software/**. We discussed some background to LTspice and SPICE simulation in general last month. If you are interested in circuit design, it is worth exploring the use of this tool. There is plenty of online discussion on LTspice, including the Yahoo Groups forum at **http://tech.groups.yahoo.com/group/LTspice/**.

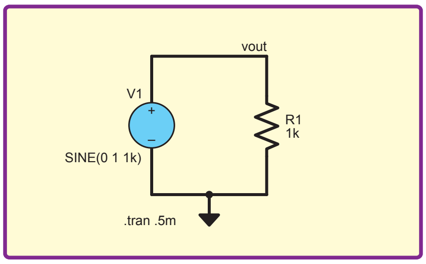


Fig.1. A very simple circuit for investigating spectra in LTspice

Select 'New Schematic' from the File menu to create a new schematic. Click on the resistor symbol on the tool bar and then on the blank schematic to add a resistor, it will automatically be labelled R1, with resistance R. Press the escape key (Esc) to stop adding resistors. Right-click on the 'R' by the resistor (not the 'R1') and enter the value '1k' in the dialog that opens. Click on the ground symbol (in the toolbar) and add that to the schematic, as you did with the resistor.

To add the voltage source, we need to add a component which is not explicitly shown on the tool bar. To do this, click on the AND gate symbol. In the dialog, select 'voltage' and click 'OK'. Click on the schematic to add the voltage source. Press escape. Right click on the voltage source symbol (not the 'V1' or 'V'). In the dialog that opens, click on the 'Advanced' button, which will open a larger dialog window.

In the 'Function' section, select 'SINE' using the radio button. Sinewave parameter boxes will appear below. Enter the following values: 'DC offset[V]:' = 0, 'Amplitude[V]:' = 1, Freq[Hz]:' = 1k. Leave the other parameter boxes blank, click 'OK'.

Click on the wire tool (pen symbol) and draw the wiring connecting the components and ground, as in Fig.1. Press escape to cancel wire function when you have finished. It is helpful to name wires because then they are easier to find in functions of the simulator (eg, the waveform display, or FFT function).

Click the 'label net' tool (an 'A' in a box) and type 'vout' into the box in the dialog. Leave the port type as 'none' and click 'OK'. Click on the wire between V1 and R1 to label it.

Now you have to tell LTspice to perform a transient simulation, which will calculate how the circuit behaves as a function of time. This will provide a waveform which we can subject to spectral analysis. Select 'Edit Simulation Cmd' from the 'Simulate' menu. This should open a dialog with the 'Transient' tab selected – if not, select that tab. Enter '5m' in the 'Stop Time' box, leaving the other options blank or unchecked. Click 'OK' and click the schematic to add the transient command ('.tran 5m').

Simulation

The circuit is ready for simulating, but first you should save it. Use 'Save As' from the File menu and select a suitable folder and file name. To run the simulation select 'Run' from the 'Simulate' menu. A blank waveform (.raw) display window will open. To see a waveform, right click in the waveform window and select 'Add Trace' from the menu. In the dialog, click on 'V(vout)' to select the voltage on the vout wire and click OK. The full waveform from the transient simulation

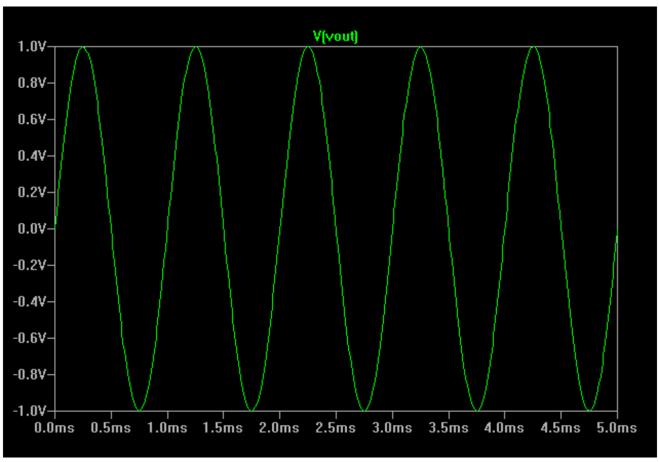


Fig.2. The waveform from the transient analysis

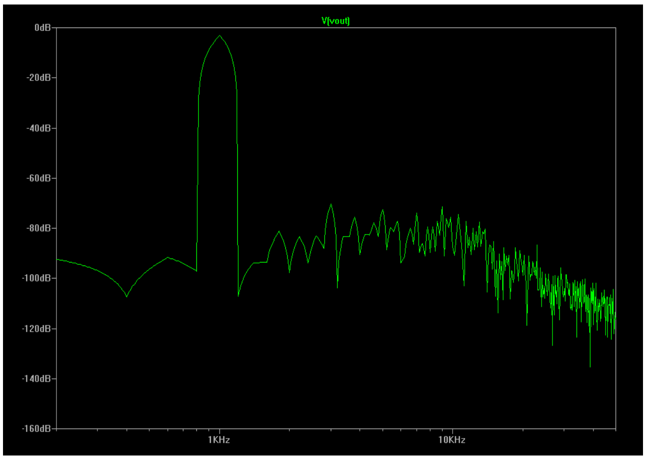


Fig.4. The initial spectrum does not look very convincing

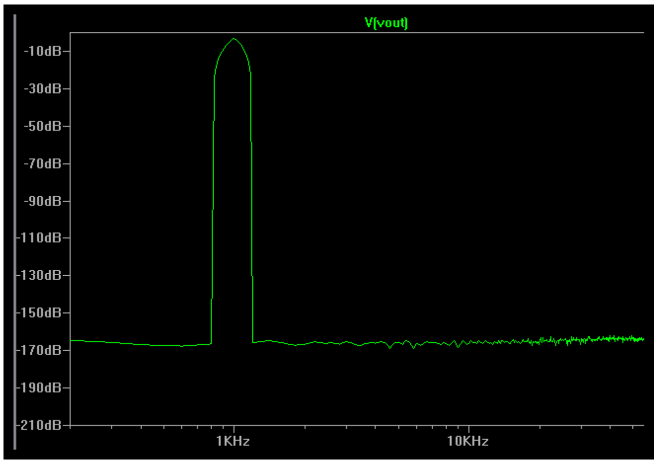


Fig.5. Avoiding data compression greatly reduces noise in the spectrum

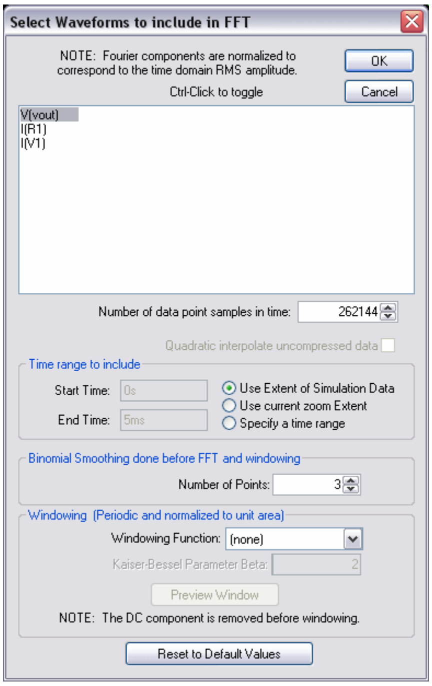


Fig.3. The FFT dialog in LTspice; understanding the parameters set in this dialog is necessary to get the best out of spectral analysis

(five sine cycles) should be displayed, as shown in Fig.2.

To see the spectrum for the waveform, right click on the waveform again and select 'View ▶' (at the bottom of the menu) and then 'FFT'. The dialog shown in Fig.3 will appear. Make sure 'V(vout)' is selected and click 'OK'. This should display the spectrum shown in Fig.4 – we have not included all the very high frequencies in this plot. This produces something like what we think 741 saw to prompt his question. The expected spectrum for a pure 1kHz sinewave is simply a single very sharp peak at 1kHz.

The spectrum in Fig.4 has a very wide peak and plenty of noise at other frequencies. Fortunately, there are a number of things we can do to obtain a more convincing spectrum.

Compressing matters

One problem is due to the fact that LTspice compresses waveform data as it is generated. This is often useful because a compressed waveform file can be 50 times smaller than an uncompressed one. However, the compression is lossy, which means that information is lost during compression. This loss may degrade the quality of a spectrum calculated from the waveform data, so when intending to analyse spectra data, compression should be turned off.

You can turn off compression using 'Control Panel' from the 'Tools' menu, going to the 'compression' tab and setting 'Window Size (No. of Points):' to zero. However, this setting is not remembered between program invocations, so it is better to put the command on the schematic.

To do this, first make sure that you have focus on the schematic window, not the waveform or spectrum, because the menus change depending on which window is active. With the schematic window selected, select 'Text' from the 'Edit' menu and check 'SPICE directive' in the 'How to netlist this text' section of the dialog. Enter the following text into the box *.option plotwinsize=0* and click on the schematic to add the command. (Don't miss the dot before 'option, this is used by LTspice to identify the text as a command).

Run the simulation again (this is necessary to generate the uncompressed waveform data). Then display the spectrum again. It should now show far less noise, particularly at lower frequencies. See Fig.5.

The decibel scale appears to exaggerate the noise level if you are not used to reading decibel-scaled graphs. In Fig.4 the noise floor is about 70dB below the peak for the 1kHz signal, this means the voltage is over 3000 times smaller. On Fig.5, the noise floor is around 160dB below the peak, this is a voltage 100 million times smaller than the peak.

We now have a clean spectrum, but the peak is still much wider than expected. This is due to not really having enough good waveform data for the FFT to use. One thing we can do is to run the simulation for longer, so that more waveforms cycles are included.

To do this use, 'Edit Simulation Cmd' from the 'Simulate' menu and change the Stop Time to '50m'. Run the simulation again and you will see about 50 cycles. In general, the simulation time (used for the FFT) should cover at least five to ten cycles of the lowest frequency of interest. The spectrum should now look like Fig.6.

The peak at 1kHz is now much narrower, but the noise floor is much worse. This is again due to lack of accuracy in the simulation. This time it is not data compression, but the number of data points at which the simulator has calculated the waveform, which is the problem. The data points used by the FFT are not at the same points in time as the points on the waveform calculated by the simulator. This is simply because they work in different ways.

Time steps

The FFT uses regularly spaced samples, whereas the simulator calculates the waveform

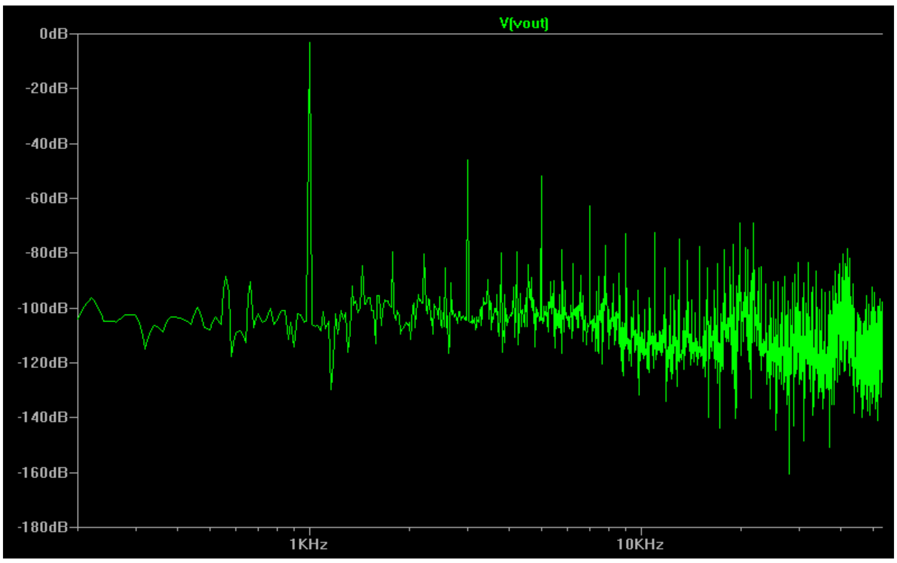


Fig.6. Using a longer simulation (more cycles) gives a narrower peak, but this attempt has more noise due to lack of simulation accuracy

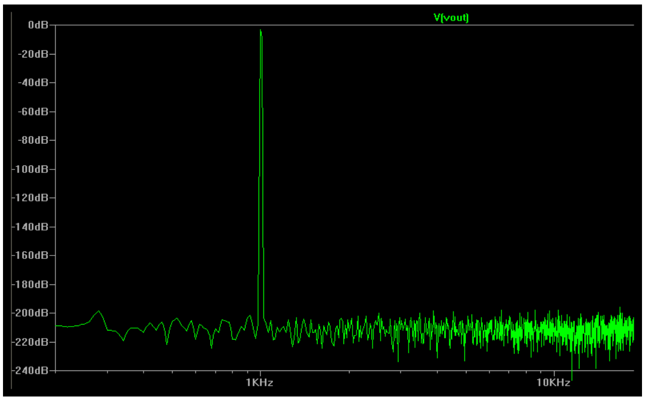


Fig.7. Improving simulation accuracy (at the expense of run time) gives a spectrum with a much better noise floor

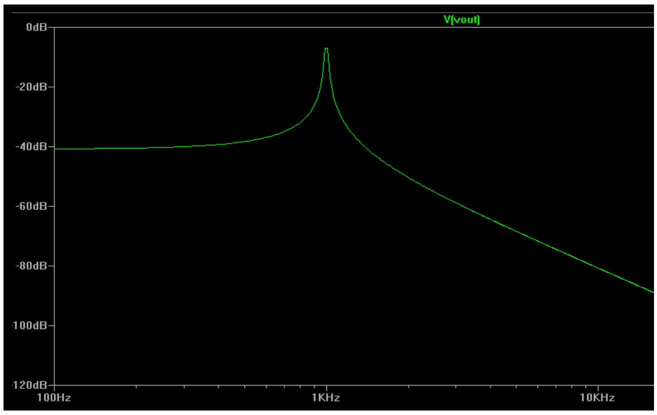


Fig.8. Using the wrong time range for a periodic signal produces an inaccurate spectrum

at the 'next time step', this length of time can vary depending on how the simulator's calculations perform. If there is not an actual simulator waveform data point at the time required by the FFT, then the FFT has to interpolate the required value using the nearest data points, which may lead to errors. We can force the simulator to use a certain minimum time step, so that more waveform data points are calculated during the simulation, providing better data for the FFT.

To reduce the time step, again use 'Edit Simulation Cmd', this time entering '10n' in the 'Minimum Timestep' box. Leave the Stop Time at '50m'. This will force the simulator to calculate waveform data points at least every 10 nanoseconds.

Run the simulation again – you will now find it takes much longer. If it takes too long (eg on a slow PC) then increase the minimum time step (eg to 50ns). View the spectrum again; it should look like Fig.7. We now have a sharp peak and a noise floor well below the peak. The spectrum is much closer to that of an ideal sinewave than our initial attempt.

The FFT dialog provides a variety of settings which we can use to control the way in which the FFT is calculated. So far, we have only used the default settings. The number of samples used by the FFT can be changed.

The default is 262144. Increasing this value will slow the FFT calculation, but increase the maximum frequency for which the spectrum is valid (for a given time range of data used by the FFT). As we are using a low frequency here, the number of points can be reduced and still provide a reasonable spectrum. However, the accuracy will also reduce, so the peak may get wider and the noise floor higher.

The time range over which the FFT is calculated (the window) can have a significant impact on the results, particularly for periodic waveforms like our sinewave. For such waveforms, the range should be an exact number of waveform cycles. The FFT is effectively calculated on a waveform which is made up of infinitely repeated copies of the window range. Discontinuities at the ends of the range introduce errors into the spectrum.

By default, the entire simulation is used for the FFT. This may not be the best approach to use; for example, an oscillator may take several cycles before it is working in a stable way, so it would be best to start any FFT analysis after this. The FFT time range can be set in LTspice by zooming on the waveform, or by typing in specific time values.

To try this, open the FFT dialog again and select 'Specify a time range' in the 'Time range to include' section. Change the 'End time' from 50ms' to '49.5ms' and click OK to obtain the spectrum. It should look like Fig.8. The peak is wide and slopes off slowly.

As we discussed last time, windowing functions can be used to 'fade out' the edges of the time range to prevent any discontinuities causing spectral leakage. Normally, these would not be needed for periodic waveforms such as sines – if we correctly used an exact number of cycles. However, we can demonstrate the effect of windowing using the situation we set up for Fig.8. Open the FFT dialog again and set the End Time to 49.5ms, but this time also set the windowing function to 'Blackman' using the drop-down list.

Despite the out-of-kilter time range, a reasonable spectrum will be produced (similar to Fig.7). For complex non-periodic waveforms we cannot choose an ideal time range, so window functions need to be used.

In this article we have looked at some aspects of obtaining a good spectrum from the FFT function in LTspice. There are other issues, complexities and options which we have not discussed, but the points we have covered should help 741 and others obtain useful spectra.

PIC n' Mix

Mike Hibbett

Our periodic column for PIC programming enlightenment

A PS/2 keyboard and mouse interface for Propeller – Part 3

IN our last article (Oct '10) we brought the Propeller's video interface to life. While an impressive feat for such a small device, we need some form of user interaction with the hardware, and so this month we will look at equipping the design with a PS/2 keyboard and mouse interface.

Straightaway, we face a number of design decisions that can affect the overall hardware design of our long-term project – creating an 'Internet Device'. Should we use USB or PS/2 keyboards? Should the keyboard connect to the PIC processor or the Propeller? Which processor will actually be in charge of displaying text on the screen?

The third way

The choice of interface type was the more difficult question. As many of you will know, the PS/2 is a very simple interface to connect to and use, but it is very dated, and keyboards or mice with this interface may be difficult to obtain.

Given that more modern keyboards and mice actually offer no or very little added value, we investigated just how readily available the older style interface products are. To our (happy!) surprise, products are still very much available, and it was even possible to source a new PS/2 keyboard from a local supermarket.

Some older keyboards are actually still very much in demand (probably due to their higher manufacturing quality) and are readily available on eBay. So a decision to use the PS/2 interface does not seem short sighted or retrograde.

The choice of which processor to connect the keyboard and mouse to is reasonably arbitrary as the data rate from the devices is quite low. We will have a high speed UART interface between the two processors too, but in the end we decided on connecting the two devices to the Propeller processor. The decision came down to the availability of software drivers for the Propeller and the fact that it helps keep the Propeller as a nicely self-contained 'media processor', leaving the PIC for the overall control application.

The latter design decision raised the final question – which processor will be in control when a key press is echoed to the display? There are two choices: Use the Propeller processor to display the character as well as send it over the serial link to the PIC, or have the Propeller act as a completely 'dumb terminal' and simply send the character to the PIC, allowing the PIC to decide if the character should be printed.

In the end, we chose a third way: provide an option within the Propeller processor to allow it to do either. This way, whether a character is immediately echoed to the screen or not can be a decision made by the PIC application, which we will create later on. If in doubt, offer both!

Looking forward, we envisage that the UART interface between the two processors will implement a protocol not unlike that used by the VT100 dumb terminals of old. The ASCII 'ESC' character is used by the protocol to allow commands to be sent to the display terminal; commands such as 'move to coordinate X,Y' or 'Change colour to BLUE'. We will create our own simplified protocol later on; for now, the important point is to create a physical design that can support it.

PS/2 sockets

For the keyboard and mouse interface we are going to need two PS/2 sockets. While these can be purchased individually or as a combined two-socket part, in keeping with the 'Recycle' theme, we went off in search of an old PC. The local recycling centre staff were hesitant at first when I arrived wanting to take stuff away rather than dumping some, but once I mentioned that I was looking to recycle parts from a computer for personal use they were more than happy. If a little bemused!

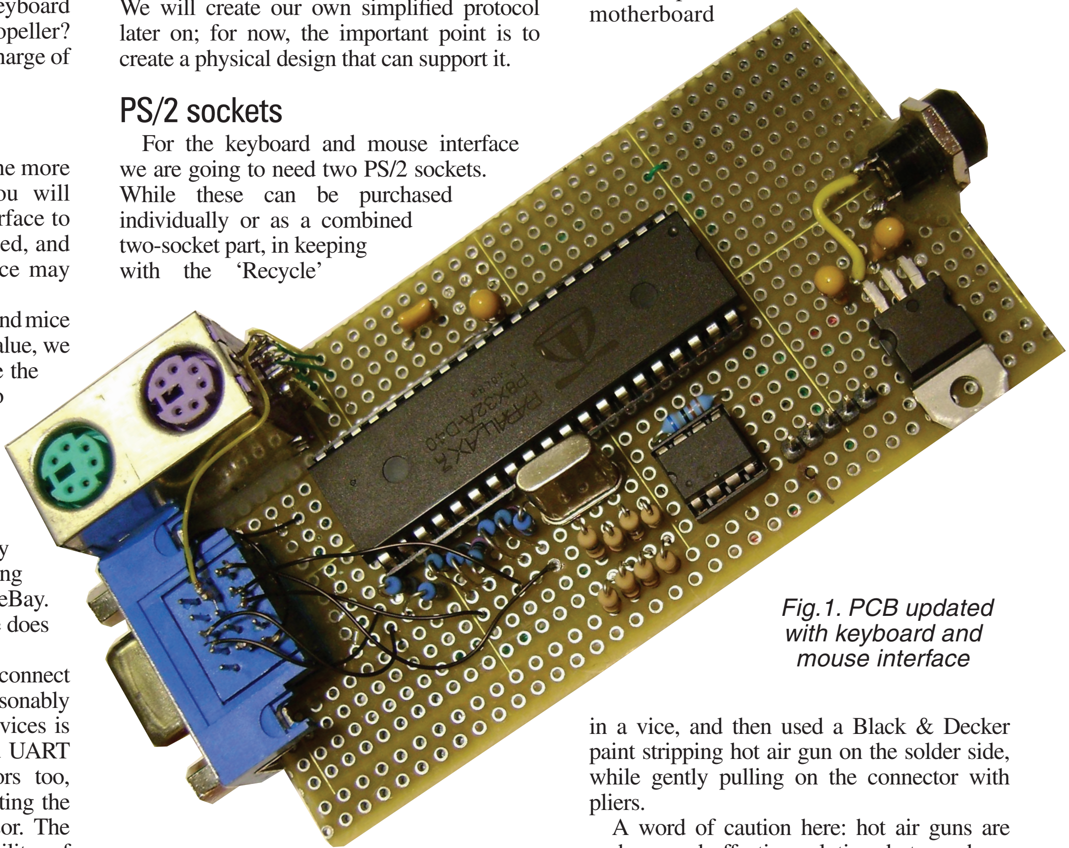


Fig.1. PCB updated with keyboard and mouse interface

I chose a combined keyboard and mouse socket, for two reasons: first, it's a smaller solution, easier to fit to our PCB; second, it's physically a more robust solution. If you decide on two individual sockets, be sure to get correctly colour-coded ones. The software on the Propeller processor expects a keyboard on the keyboard socket and cannot auto-detect what is connected. The colour coding standard makes it easier for the user to match the correct device to the correct socket (a standard that was long in coming, in our opinion.)

Salvaging

Salvaging a large connector from an old motherboard can be a challenge, so if you haven't done this before we recommend you practice first on a spare motherboard or two. We clamped the motherboard in a vice, and then used a Black & Decker paint stripping hot air gun on the solder side, while gently pulling on the connector with pliers.

A word of caution here: hot air guns are a cheap and effective solution, but you have no control over the temperature. It is easy to overheat the PCB to the point of setting it alight, giving of toxic fumes, not to mention being a serious fire hazard. Do this somewhere well ventilated and away from anything flamable or valuable. On the garden patio in our case!

Put the socket somewhere safe to cool down before checking for damage, then use a soldering iron to tidy up the pins. Once cooled, we glued the socket to our PCB using two-part epoxy resin, although hot-melt glue would make for a semi-permanent though less mechanically stable arrangement. You can see our final assembly in Fig. 1.

Tip: Keep some of the left over epoxy mixture to hand rather than disposing of it immediately. This way, if you are in a hurry to

continue working on your board you can test the left over mixture to judge when it has set.

At this point, you need to work out where the pins on the connector go. There are only four connections used on the PS/2 interface, which on a dual socket means eight connections to locate. We did this using a short wire to probe into the socket itself and a DVM to detect continuity.

Fig. 2 shows the signal names and pinout for the socket, *as seen from the socket end*; ie, where you would plug the connector in. Unless you have a photographic memory, we recommend that you draw a clear diagram of the pin connections as you check continuity; we had to rewire ours twice due to twice mis-reading a poorly drawn diagram!

Circuit changes

The PS/2 interface requires just four resistors, making it a very simple addition to any circuit. Two pull-up resistors on the data and clock lines, and two series resistors to protect against static discharge damage.

The revised circuit, showing just eight additional resistors, is shown in Fig.3. Note that while the pull-up resistors go to 3.3V, the supply pin on the PS/2 connector should be tied to 5V – hence the original choice of a 5V PSU for the circuit.

RS232 Interface

Now for the easy bit, wiring up the UART interface that will connect the two processors together. There is nothing to do – we can completely re-use the Propeller's programming interface, allowing us to develop and test the Propeller's UART message protocol on the PC without any further wiring.

With the circuit and software presented in this article you just need to open a serial communications program, such as Hyperterm (although we recommend the free program TeraTerm), set the interface to 115200 8,N,1 and you can immediately communicate with the Propeller processor.

The Programming interface is required to communicate with a PC; when we connect the PIC to the Propeller there will be no voltage level conversions required, and we will simply connect the TX and RX pins together with no additional components.

For our processor-to-processor interface we are actually going to wire up two links – one based on a UART, for the sending display data and receiving keyboard/mouse events, then another based on the SPI protocol for sending stereo audio data. Two links may turn out to be overkill, but it's better to have a spare than to find our design limited by the available bandwidth of a single link.

Even at low data rates, stereo audio will require a fair amount of data bandwidth, so it's wise at this stage to provide some contingency. The SPI interface will require just a single pull-up resistor, but we will cover that after we have hooked up the PIC processor.

The Propeller processor will also provide two interrupt output signals, one for each communication link. This will allow the PIC processor to respond quickly to events occurring on the Propeller without tying it up in a constant polling loop waiting for data. What these 'Events' are is left undefined for now, until we better understand what the application will do.

At this stage, where we are trying to develop the video, keyboard and mouse interface, debugging is a dream. Using the Propeller Tool's 'Load RAM' compile option means that you can edit code and then compile, download and restart the hardware with a single keystroke – all within a couple of seconds. No fiddling with cables, no switching things on and off. It's a very efficient process, especially if you like making quick coding hacks.

Software

So now we have a keyboard, mouse and RS232 interface available, it's time to get interactive. The supporting software libraries from Parallax and their contributors are very easy to use, and we were able to produce a simple test application based on existing

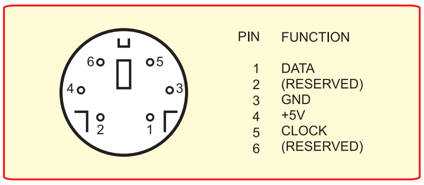


Fig.2. PS/2 female socket

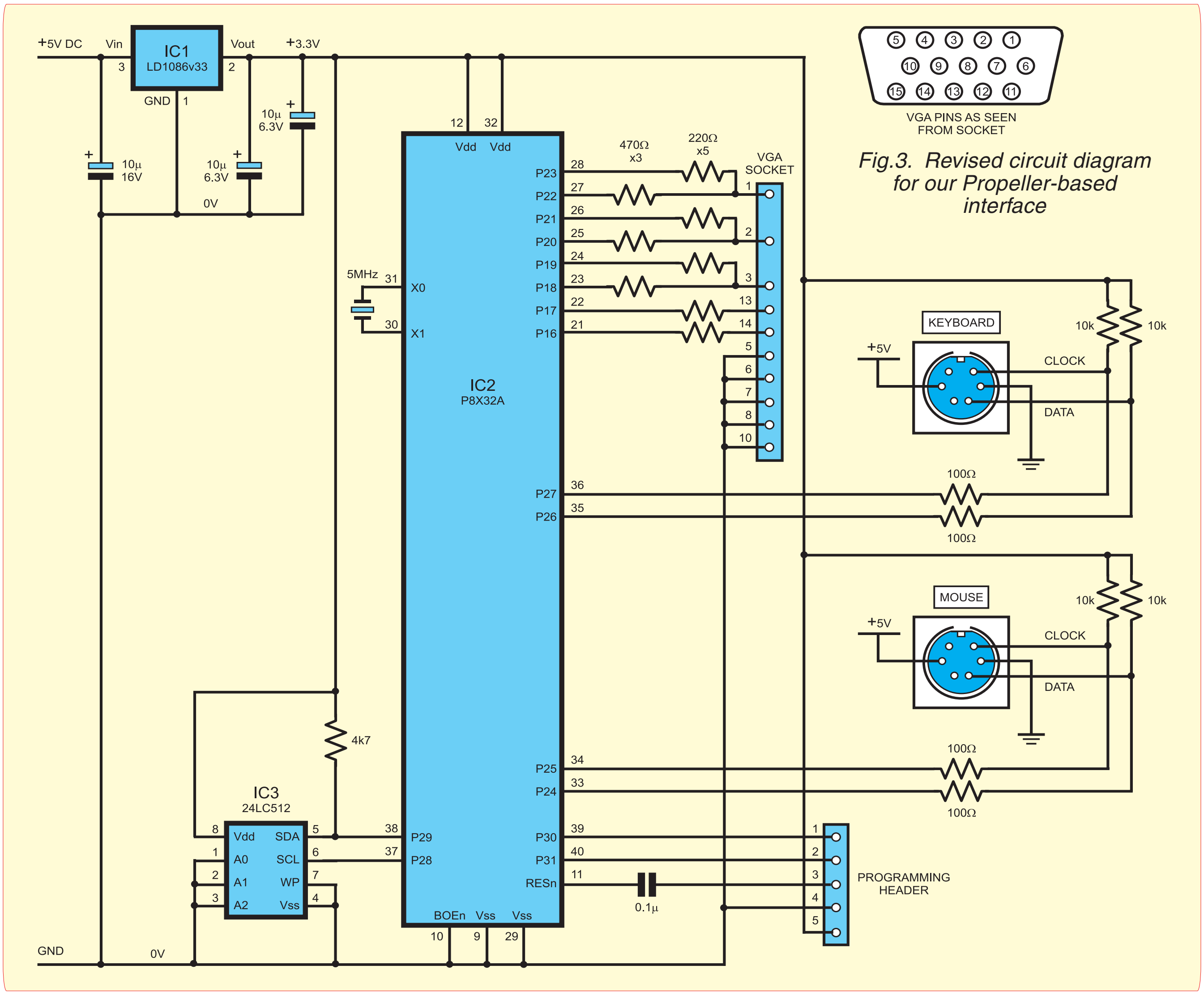


Fig.3. Revised circuit diagram for our Propeller-based interface

demonstration code. The resulting source code can be found on the *EPE* website under this month's issue in file **propeller3-src.zip**.

Our test application is 100 lines in length, excluding the library modules for the PS/2, RS232 and video libraries. The main logic looks like this:

```
'main loop - mouse controls stuff
repeat
  cx0 := mouse.bound_x
  cy0 := mouse.bound_y
     if mouse.button(0)
    cx1 := mouse.bound_x
    cy1 := mouse.bound_y
       handle_rx
      if keyboard.gotkey
    putch( keyboard.key )
```

This is a simple loop that reads the mouse position and move a cursor to it. Any key presses are echoed to the screen, as are any characters received from the UART interface. Not very useful yet, but sufficient to test that the interfaces work.

To view the source code, extract the files from propeller3-src.zip and double-click on the file **MediaProcessor.spin**.

That's all for this month; next month we look at creating the UART communication protocol software and prepare for interfacing to the PIC processor.

3D Printer Update

It's been a year since we covered the *RapMan 3D* printer from BitsFromBytes, so we caught up with managing director Ian Adkins this week to see how things had been progressing. BitsFromBytes have made the press recently after having been bought out by US company 3D Systems, manufacturers of high end 3D printer products.

In the first year of commercial trading, BitsFromBytes have accounted for 17% of world 3D printer sales – a fantastic achievement, especially as the company started off in the garage at Ian's home. They now have a 4000 square foot facility and a staff of fourteen.

They shipped over 1000 kits in the last year, mostly to the educational and hobbyist market. Given the challenges of supporting a complex kit through a rapid increase in sales with such a small support team (just two of them at first) I asked Ian how they managed to cope.

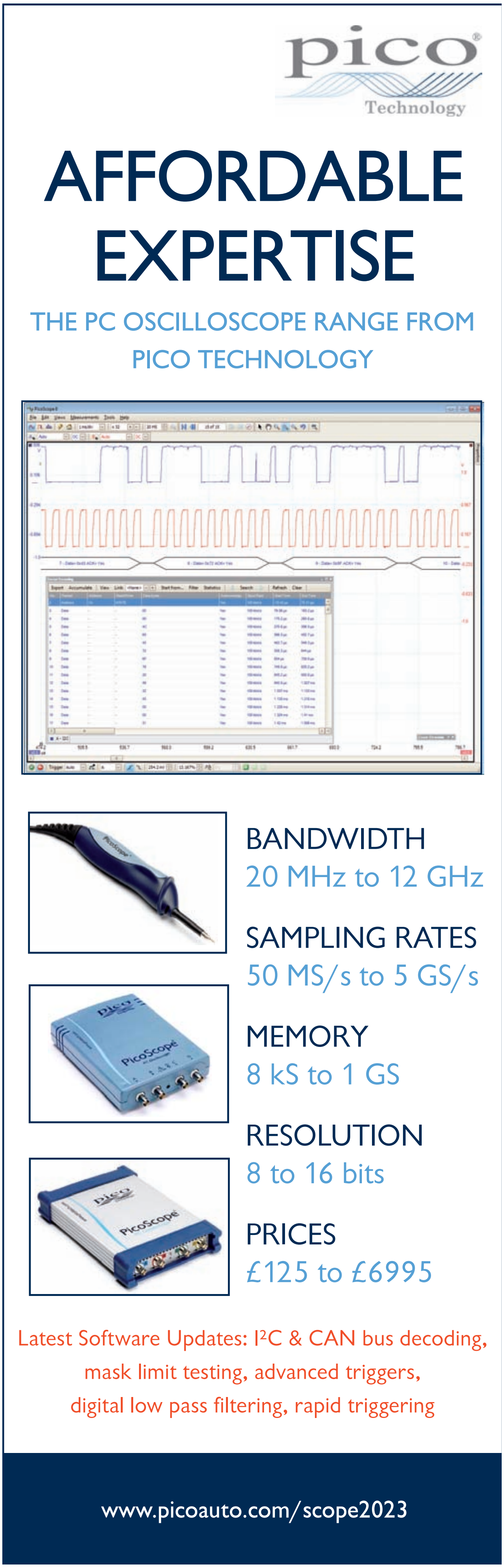
'Eighteen months ago I would not have dared dream of the success the RapMan kit has achieved in such a short time period. As the volumes increased we made incremental changes to the kit, simplifying its assembly.

The core support of the product, however, has been through the online community that has developed on our forum. I don't understand how some of them fit the time in with their full time work. The success of RapMan owes a lot to the friendliness and carefully considered feedback and encouragement that so many of the forum users offer.'

The investment by 3D systems enables BitsFromBytes to improve their manufacturing process, with an aim to be able to prepare dozens of kits per day. 'More importantly,' says Ian, 'working with 3D systems gives us access to their considerable experience and skill in the 3D printer market. They recognise the new market that is opening up in the sub-£1000 and sub-£4000 price range, and fully support both our product approaches: the low-cost open-source RapMan platform and the higher end BFB 3000'

It's been very interesting to watch the evolution of hobbyist 3D printing solutions over the last two years, and we wish Ian and his team continued success, and by the sounds of it, fun! It's great to see a UK manufacturing company succeed in such difficult economic times.

BitsfromBytes website can be found at: **www.bitsfrombytes.com**



INTERFACE

By Robert Penfold

Old-tech relays still have their uses today!

Many of the recent articles in this series have been concerned with the problem of getting bits or bytes of data into or out of a PC, which is something that seems to have become more difficult over the years. It is also an aspect of PC interfacing that undergoes frequent changes. In this article, the electronics beyond input/output ports will be considered.

In contrast to computer ports and programming languages, this is an aspect of things that has not really changed a great deal since the early days of home computing. Many of the techniques used with the old BBC Model B computer work equally well with a modern PC equipped with a suitable input/output port.

Golden oldie

A relay is an old-tech component that consists of a mechanical switch operated by an electromagnet. Although relays might seem out of place in modern circuits, and especially so when used with the latest hi-tech computers, they still represent the best solution in many simple control applications.

Rather than becoming obsolete, relays seem to be used more than ever before. On checking one of the large online component catalogues to see if a good range of relays could still be obtained, I found that a few thousand different types were listed!

Probably the main reason for the continuing use of relays in modern electronic designs is that there is complete electrical isolation between the coil of the electromagnet on the input side of the component, and the switch contacts on the output side. With many real-world applications this isolation is essential, and a previous *Interface* article covered the use of opto-isolators to avoid problems when interfacing a mains powered PC to other mains powered equipment.

Opto-isolation is usually unnecessary when using relays, with the relay providing the only isolation required. The built-in isolation also means that there are no problems when controlling mains-powered loads. The relay keeps the potentially fatal mains supply voltage away from the controlling circuit, and again, this is normally the only isolation that is required.

Although relays tend to be associated with power switching, they can also be used in applications where low level signals are being controlled. Electronic switches are the more normal choice for this type of thing, but these devices have a few drawbacks. One of these is that there are usually some restrictions on the ways in which the switches can be used, whereas there are 'no strings attached' when using relays.

With relays, there are no problems with switching signals from the control circuit introducing 'clicks' into the signal path. Electronic switches tend to introduce distortion and signal losses when in the 'on' state, but these issues do not arise with relays and their largely resistance-free mechanical switches.

The simple switches of relays are also an advantage in power applications. There is always a small voltage drop when using a semiconductor switching device such as a power transistor or a triac. The loss of power is not normally significant, but it produces heat in the switching device and a heatsink is often required in order to prevent overheating. With a relay, there is no significant power loss and no heat generation to contend with.

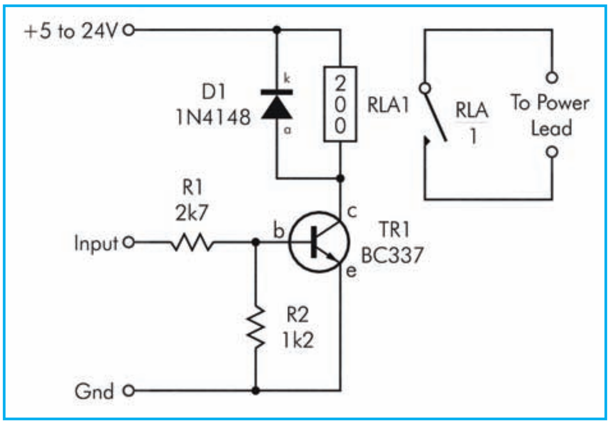


Fig.1. A simple relay driver using a common emitter switch. The resistance of the relay coil can be anything from about 50 ohms to several hundred ohms, but the current should not exceed much more than about 100mA

Drawbacks

Although relays have advantages, there are a few drawbacks as well. Being largely mechanical in nature, they do wear out, and they are relatively slow. A large electronic switching device can typically complete a million on/off cycles in a few seconds and will be none the worse for the experience.

A relay typically takes a few milliseconds to switch on or off, and completing a million on/off cycles would therefore take at least a few hours. The component might wear out and fail long before completing this task. Obviously, only very infrequent switching is involved in many applications, and the lack of speed and longevity of a relay are then unlikely to be issues.

Another point to bear in mind is that the power required to drive a typical relay coil is quite high by current standards, and this becomes of greater significance with circuits that use several relays. Further points to bear in mind are that relays can be quite noisy in operation, and the lager types can be very noisy. The switching action is a mechanical type, and one can reasonably expect a certain amount of electrical noise to be produced by so-called 'contact bounce'.

Most of the parameters associated with relays are perfectly straightforward, but it is still necessary to exercise a degree of care when selecting one. Here are some points that are worth noting.

Coil resistance

As pointed out previously, the solenoid of a relay often requires a fair amount of power by the standards of modern circuits. The specification for a relay does not usually state a power or current rating for the solenoid, but instead gives the nominal coil voltage and resistance. The other parameters can be calculated from these with the aid of Ohm's Law.

It is definitely a good idea to work out the operating current, which is equal to the coil voltage divided by its resistance. In general, the lower operating currents provided by higher coil resistances are to be preferred, and this is especially the case when several relays are used.

Contact ratings

Few relays provide simple on/off switching. It is quite normal for there to be something like two, three, or even four sets of changeover contacts. Of course, if you simply need on/off switching, as is often the case in practice, it is just a matter of using two contacts that provide this action, and ignoring all the others. Similarly, if you need one set of changeover contacts, a relay that has two or more sets of changeover contacts is perfectly suitable. Use one set of contacts and ignore the rest.

The specification for a relay should include the maximum voltage and current ratings for the contacts, but it is a good idea to study the contact ratings carefully. The AC and DC ratings are often different, and both figures might be substantially lower when controlling an inductive load such as an electric motor. Purely from the electrical standpoint, there is no problem in using a relay that has contact ratings which are massively higher than the minimum requirements for a given application.

In practice, relays that can control high power loads tend to be relatively large, noisy, expensive, and have coils that operate at quite high currents. It is, therefore, worthwhile seeking one that comfortable exceeds the minimum requirements, while avoiding relays that are completely 'over the top' for your application.

Relay drivers

There are relays designed to be driven direct from a suitably high current logic output, but the ones I have encountered are only suitable for low power and low voltage loads. A relay normally has to be driven via a simple driver stage, which can be a common emitter switch, such as the one shown in Fig.1.

Feeding a high (logic 1) signal to the input of this circuit switches on transistor TR1 and activates the relay coil. Using a low (logic 0) input signal switches off TR1, which in turn cuts the current to the relay coil. The potential divider at the input (R1 and R2) ensures that TR1 is cut off when the input is at logic 0, even if the driving circuit is one that provides a potential of a volt or so at this logic state.

Diode D1 may appear to serve no purpose, but it is essential when using a switching transistor to drive any highly inductive load such as a relay coil. The purpose of the diode is to suppress the high reverse voltage that is generated when the relay is switched off, and the magnetic field of the solenoid collapses. Semiconductors are very intolerant of high voltages, and even though this reverse voltage spike is at a high impedance it could easily damage TR1, and possibly semiconductors in the circuit that drives TR1.

There are special relay driver chips available, which provide a neater solution in applications where several relay drivers are required. However, some of devices are relatively expensive, and most of the devices currently available seem to be aimed primarily at various types of complex motor control.

Driver circuits based on discrete components are often a more practical choice. Some logic buffer devices are capable of driving small relays, and offer a possible low-cost solution where several relay drivers are needed.

Higher power

Relay driver circuits can actually be used to drive practically any small DC loads, including things like small filament bulbs, LEDs, and small electric motors. Some loads, including most electric motors, require higher currents than the 100mA or so that a relay driver can provide.

One solution to the problem is to simply control the load via a relay, but with most low voltage DC loads it is more straightforward to use a high power semiconductor switch. A power Darlington transistor is well suited to applications of this type, where the high current gain avoids the need for a driver stage, and the relatively low switching speed is of no consequence.

The circuit for a simple DC power driver is shown in Fig.2, and the leadout diagram for the TIP122 Darlington is provided in Fig.3. The circuit is much the same as the one for the standard relay driver, but the values in the potential divider have been changed to suit the higher forward threshold voltage of the Darlington transistor. The load can have a current consumption of up to about 4A.

A heatsink is required for TR1, but one of the small finned types designed for use with types that have a TO-220 case should suffice. The power dissipation in TR1 is low because it is either switched off, with no significant load current flowing, or it is switched on, and the collector to emitter voltage is quite low. Obviously, there is some voltage drop through TR1 when it is switched on, and with a current flow of a few amps, even a couple of volts or so dropped through TR1 results in it having to dissipate several watts.

It should be noted that the supply voltage on the output of the circuit might have to be increased in order to compensate for the voltage drop through TR1. The loss of a couple of volts is significant, even with a fairly high supply potential of about 24V, and it is massive if the supply potential is only about five or six volts. Once again, an old-fashioned relay with its zero losses might be a more practical solution in some applications.

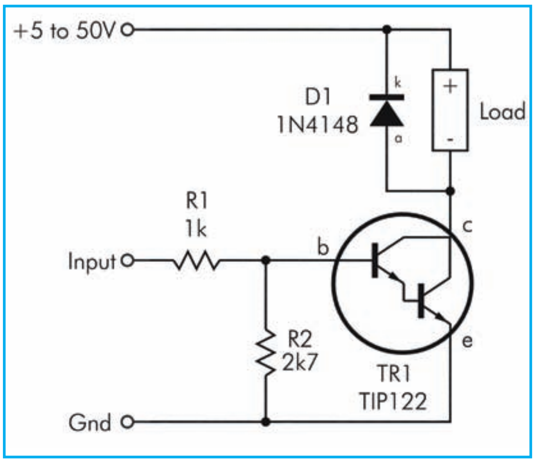


Fig.2. A circuit that can control DC loads of up to 4A. There is a voltage drop of up to roughly 2V through TR1, which will require a heatsink for output currents of more than about 0.5A

Triac isolator

There is a special type of opto-isolator that provides a simple alternative to a relay when simple on/off control of a mains load is required. The MOC3020M is an example of an opto-isolator of this type. It consists of the usual infra-red LED on the input side, and a triac on the output side. Since there is no gate connection, I am not sure if it is actually a triac, and it might more accurately be termed a diac.

Anyway, the output device can only handle low currents, with a maximum of just 60mA being allowed. The idea is not for the built-in triac to directly control the load. Instead, it is used to control a triac that has suitable ratings for the load being controlled.

It is used in the manner shown in Fig.4, which is suitable for use with resistive loads. On the input side, the internal LED is driven via a simple common emitter switch (TR1), and resistor R3 limits the LED current to the required level. The triac in IC1 is normally switched off, and the discrete triac therefore receives no gate current and remains switched off as well. When the LED is turned on, it switches on the triac at the output of IC1, and the discrete triac is then triggered near the beginning of each mains half cycle. The two output terminals of the circuit are used to control the load in the same way that relay contacts or an ordinary on/off switch would be utilised. There is no internal connection to pin 3 of IC1, but there is a connection to pin 5. This internal connection is not required in use though, and no external connection should be made to pin 5.

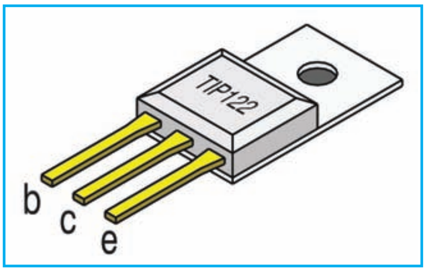


Fig.3. Pinout details for the TIP122 power Darlington transistor. It has a standard TO-220 encapsulation

The rating of the triac must be chosen to suit the given application. For use on the 230V UK mains supply it should have a voltage rating of at least 400V. There is a voltage drop of about one volt through a triac in the on state, so a small heatsink will be required if the load consumes more than about one amp.

With this circuit, or when using a relay to control mains loads, the standard safety measures **must** be observed and the completed equipment should conform to the normal safety standards. **Only those with the necessary experience and knowledge should tackle projects that connect directly to the mains supply**.

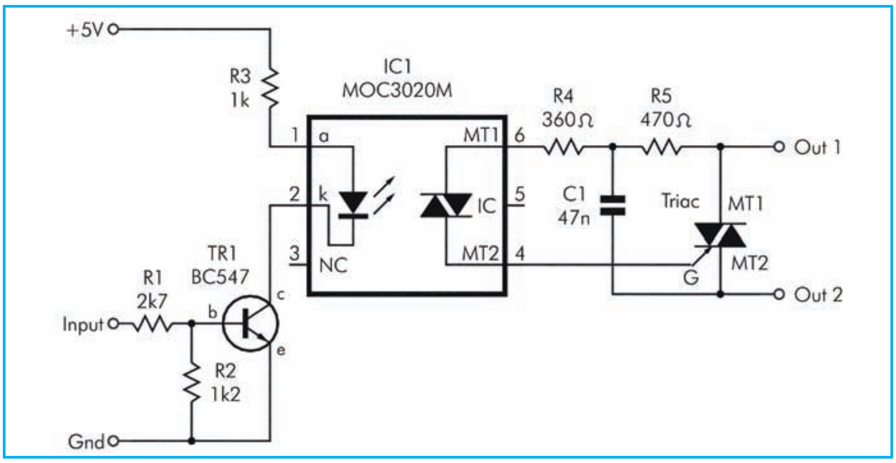


Fig.4. A circuit that provides mains on/off control without using a relay. The triac at the output must have a voltage rating of at least 400V for use with a 230V AC mains supply, and a current rating that is adequate for the load being controlled

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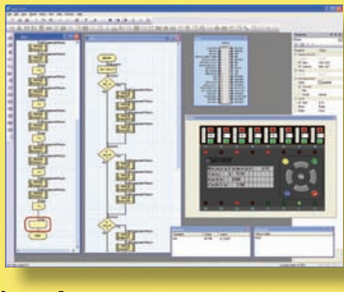

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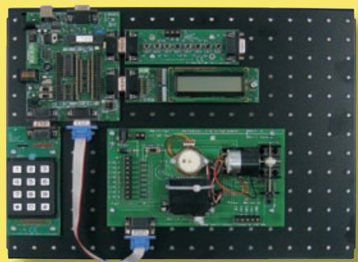

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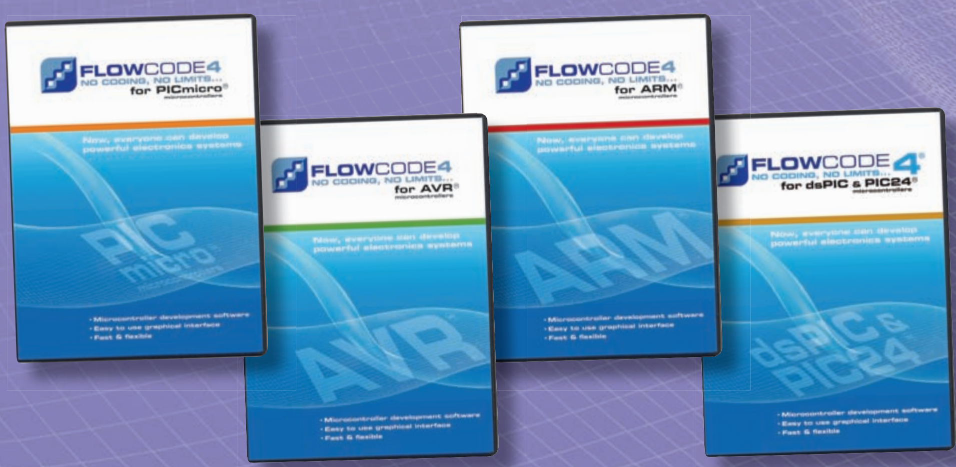

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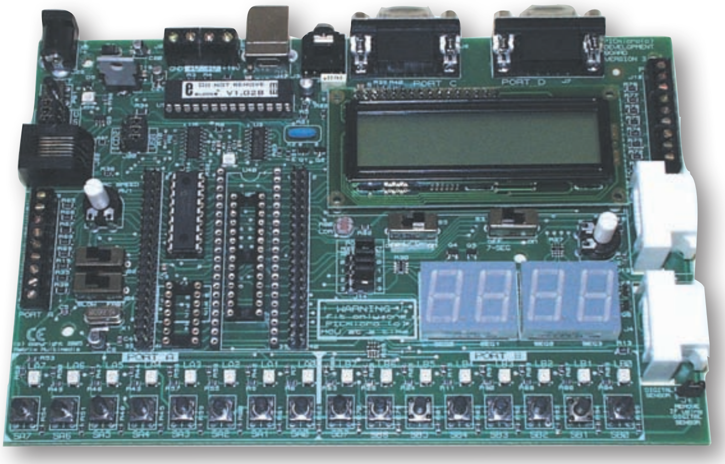

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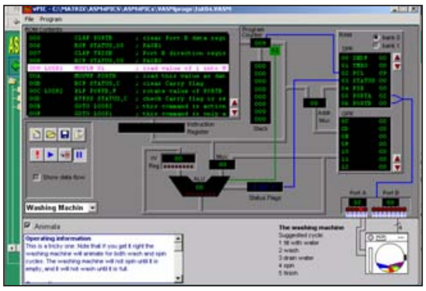
(Formerly PICtutor)

Assembly for PICmicro microcontrollers V3.0 (previously known as PICtutor) by John Becker contains a complete course in programming the PIC16F84 PICmicro microcontroller from Arizona Microchip. It starts with fundamental concepts and extends up to complex programs including watchdog timers, interrupts and sleep modes.

The CD makes use of the latest simulation techniques which provide a superb tool for learning: the Virtual PICmicro microcontroller, this is a simulation tool that allows users to write and execute MPASM assembler code for the PIC16F84 microcontroller on-screen. Using this you can actually see what happens inside the PICmicro MCU as each instruction is executed, which enhances understanding.

● Comprehensive instruction through 45 tutorial sections ● Includes Vlab, a Virtual PICmicro microcontroller: a fully functioning simulator ● Tests, exercises and projects covering a wide range of PICmicro MCU applications ● Includes MPLAB assembler ● Visual representation of a PICmicro showing architecture and functions ● Expert system for code entry helps first time users ● Shows data flow and fetch execute cycle and has challenges (washing machine, lift, crossroads etc.) ● Imports MPASM files.

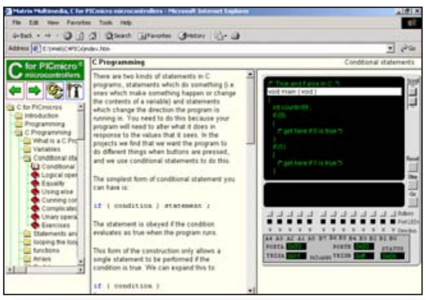


'C' FOR 16 Series PICmicro Version 4

The C for PICmicro microcontrollers CD-ROM is designed for students and professionals who need to learn how to program embedded microcontrollers in C. The CD-ROM contains a course as well as all the software tools needed to create Hex code for a wide range of PICmicro devices – including a full C compiler for a wide range of PICmicro devices.

Although the course focuses on the use of the PICmicro microcontrollers, this CD-ROM will provide a good grounding in C programming for any microcontroller.

● Complete course in C as well as C programming for PICmicro microcontrollers ● Highly interactive course ● Virtual C PICmicro improves understanding ● Includes a C compiler for a wide range of PICmicro devices ● Includes full Integrated Development Environment ● Includes MPLAB software ● Compatible with most PICmicro programmers ● Includes a compiler for all the PICmicro devices.



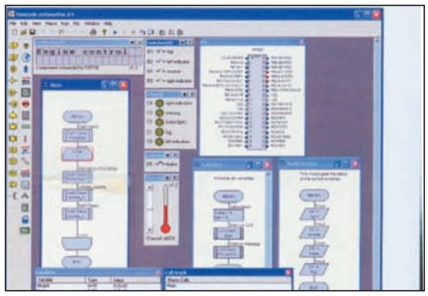
Minimum system requirements for these items: Pentium PC running, 2000, ME, XP; CD-ROM drive; 64MB RAM; 10MB hard disk space.
Flowcode will run on XP or later operating systems

FLOWCODE FOR PICmicro V4

Flowcode is a very high level language programming system based on flowcharts. Flowcode allows you to design and simulate complex systems in a matter of minutes. A powerful language that uses macros to facilitate the control of devices like 7-segment displays, motor controllers and LCDs. The use of macros allows you to control these devices without getting bogged down in understanding the programming. When used in conjunction with the Version 3 development board this provides a seamless solution that allows you to program chips in minutes.

- Requires no programming experience
- Allows complex PICmicro applications to be designed quickly
- Uses international standard flow chart symbols
- Full on-screen simulation allows debugging and speeds up the development process.
- Facilitates learning via a full suite of demonstration tutorials
- Produces ASM code for a range of 18, 28 and 40-pin devices
- 16-bit arithmetic strings and string manipulation
- Pulse width modulation
- I2C.

New features of Version 4 include panel creator, in circuit debug, virtual networks, C code customisation, floating point and new components. The Hobbyist/Student version is limited to 4K of code (8K on 18F devices)



PRICES

Prices for each of the CD-ROMs above are:

(Order form on next page)

(UK and EU customers add VAT to 'plus VAT' prices)

Hobbyist/Student	£45	inc VAT
Institutional (Schools/HE/FE/Industry)	£99	plus VAT
Institutional/Professional 10 user (Network Licence)	£350	plus VAT
Site Licence	£699	plus VAT
Flowcode Institutional (Schools/HE/FE/Industry)	£149	plus VAT
Flowcode 10 user (Network Licence)	£399	plus VAT
Flowcode Site Licence	£799	plus VAT

Special EPE Offer

CIRCUIT WIZARD

Circuit Wizard is a revolutionary new software system that combines circuit design, PCB design, simulation and CAD/CAM manufacture in one complete package. Two versions are available, Standard – which is on special offer from *EPE* – and Professional.

By integrating the entire design process, Circuit Wizard provides you with all the tools necessary to produce an electronics project from start to finish – even including on-screen testing of the PCB prior to construction!

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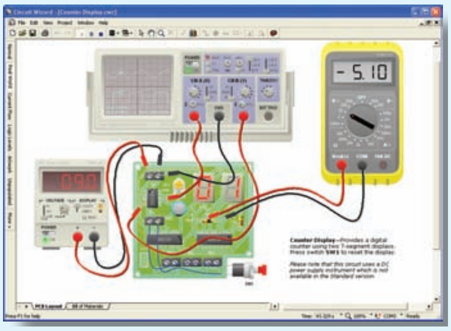


Special EPE Offer - Standard version only.

EPE is offering readers a 10% discount on Cicuit Wizard Standard software if purchased before Jan 31, 2011. This is the software used in our *Teach-In 2011* series.

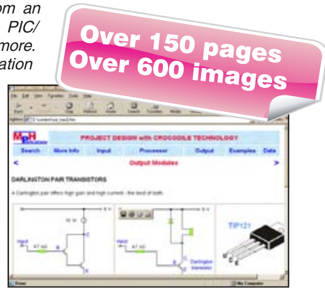
Standard (*EPE* Special Offer) ~~£59.99~~ £53.99 inc. VAT

Professional £89.99 inc. VAT

Special EPE Offer ends Jan 31, 2011

PROJECT DESIGN WITH CROCODILE TECHNOLOGY

An Interactive Guide to Circuit Design



An interactive CD-ROM to guide you through the process of circuit design. Choose from an extensive range of input, process and output modules, including CMOS Logic, Op-Amps, PIC/PICAXE, Remote Control Modules (IR and Radio), Transistors, Thyristors, Relays and much more. Click Data for a complete guide to the pin layouts of i.c.s, transistors etc. Click More Information for detailed background information with many animated diagrams.

Nearly all the circuits can be instantly simulated in Crocodile Technology (not included on the CD-ROM) and you can customise the designs as required.*

WHAT'S INCLUDED

Light Modules, Temperature Modules, Sound Modules, Moisture Modules, Switch Modules, Astables including 555, Remote Control (IR & Radio), Transistor Amplifiers, Thyristor, Relay, Op-Amp Modules, Logic Modules, 555 Timer, PIC/PICAXE, Output Devices, Transistor Drivers, Relay Motor Direction & Speed Control, 7 Segment Displays.Data sections with pinouts etc., Example Projects, Full Search Facility, Further Background Information and Animated Diagrams.

Runs in Microsoft Internet Explorer

All circuits can be viewed, but can only be simulated if your computer has Crocodile Technoloy version 410 or later. A free trial version of Crocodile Technology can be downloaded from: **www.crocodile-clips.com. Animated diagrams run without Crocodile Technology.*

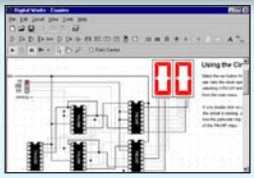
Single User £39.00 inc. VAT.

Multiple Educational Users (under 500 students) £59.00 plus VAT. Over 500 students £79.00 plus VAT.

(UK and EU customers add VAT "plus VAT" prices)

Minimum system requirements for these CD-ROMs: Pentium PC, CD-ROM drive, 32MB RAM, 10MB hard disk space. Windows 2000/ME/XP, mouse, sound card, web browser.

DIGITAL WORKS 3.0



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Digital Works Version 3.0 is a graphical design tool that enables you to construct digital logic circuits and analyze their behaviour. It is so simple to use that it will take you less than 10 minutes to make your first digital design. It is so powerful that you will never outgrow its capability ● Software for simulating digital logic circuits ● Create your own macros – highly scalable ● Create your own circuits, components, and i.c.s ● Easy-to-use digital interface ● Animation brings circuits to life ● Vast library of logic macros and 74 series i.c.s with data sheets ● Powerful tool for designing and learning.

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A high quality selection of over 200 jpg images of electronic components. This selection of high resolution photos can be used to enhance projects and presentations or to help with training and educational material. They are royalty free for use in commercial or personal printed projects, and can also be used royalty free in books, catalogues, magazine articles as well as worldwide web pages (subject to restrictions – see licence for full details).

Now contains Irfan View image software for Windows, with quick-start notes included.

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☐ Flowcode for AVR
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☐ Flowcode for dsPIC & PIC24
☐ Digital Works 3.0

Version required:
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☐ Institutional + Flowkit
☐ Site licence

Note: The software on each version is the same, only the licence for use varies.

☐ PICmicro Development Board V3 (hardware)

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Student/Single User/Standard/Professional Version price includes postage to most countries in the world
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READOUT

Email: editorial@wimborne.co.uk

Matt Pulzer addresses some of the general points readers have raised. Have you anything interesting to say? Drop us a line!

All letters quoted here have previously been replied to directly

WIN AN ATLAS LCR ANALYSER WORTH £79

An Atlas LCR Passive Component Analyser, kindly donated by Peak Electronic Design Ltd, will be awarded to the author of the Letter Of The Month. The Atlas LCR automatically measures inductance from 1mH to 10H, capacitance from 1pF to 10,000μF and resistance from 1Ω to 2MΩ with a basic accuracy of 1%. www.peakelec.co.uk

☆ LETTER OF THE MONTH ☆

Old school FFT analysis!

Dear Editor

The very interesting *Circuit Surgery* article on the Fast Fourier Transform (Nov '10 issue) reminded me of flutter work with the Filton Wind Tunnel Department of British Aircraft Corporation and British Aerospace. Projects included *Concorde* and most of the *Airbus* range, as well as various industrial structures.

Most analysis was carried out using an FFT analyser, which was about the size of a wardrobe, using data recorded on large reel-to-reel tape recorders and paper tape.

The models were beautifully constructed by our model-makers, from etched aluminium sheet, glass or carbon fibre, foam and balsa wood. Instrumentation included lots of (expensive) strain gauges and miniature accelerometers, which in the early days were wired to op-amps hand-made from transistors (no 741s back then!).

The whole model had to simulate (to scale) the correct mass distribution and stiffness of the full-size structure, and the wind tunnel tests (hopefully) proved that the aerodynamic exciting forces were well out of phase with the natural frequency of the wing at all service speeds (up to about Mach 0.9 for the *Airbus* projects).

A lot of testing was carried out in the blow-down supersonic tunnel at Warton, Lancashire. Sometimes the sums were wrong and the model disappeared in a brief blur, hopefully caught on high-speed cameras, and we would then spend a few unhappy hours picking up bits of the model from the fens down-wind of the tunnel.

The attached photo shows a 1/100 scale 'flutter' model of a flare boom for a North Sea oil platform, in the Filton Wind Tunnel. This beautiful model was constructed from various thicknesses of hypodermic tubing, brazed together to simulate the correctly scaled mass and stiffness.

It was mounted on five multi-axis strain-gauge balances at the attachment points, and also carried many accelerometers to log the dynamic response to various wind speeds and directions.

FFT today? – it's available at the touch of a button on my relatively cheap Rigol oscilloscope – how electronics has progressed!

Roger Redman, Holcombe Farm, near Moorlinch, Somerset

For the odd reader who thinks FFT analysis of structures is a 'bit over the top', have a look at this clip, which shows just what happens when you don't check the resonance risks: www.youtube.com/watch?v=gHgQALH9-7M

More – NOT fewer – PICs please!

Dear Editor

Having just read the September issue of *EPE*, I feel I have to write to give a diametrically opposite view from your 'Letter of the Month': for me, you could never have too much PIC-related content! If you wanted to reduce content in certain areas, may I suggest anything that you can buy off the shelf that is cheaper, better or safer. For example, why would anyone build a power amplifier? Similarly, the *Balanced/Unbalanced Converter* is pointless, no professional is going to allow a piece of home-brew kit to be connected to their very expensive equipment. Other areas where you could save space include: printing the resistor colour codes on almost every project, and showing readers how to bend a lead!

For me, electronics at the hobby level should be focussed on kit that is expensive to buy, niche products, and cool stuff. Off the top of my head: Marine VHF/AIS receivers, digital marine fuel tank monitor, PIC-based USB scope, tracking device with GSM interface and GPS, worldwide R/C clock, PIC/PC atmospheric pressure logger, GSM house/car alarm alert, reusing mobile phone LCDs, UV LED PCB exposure unit, robotic arms or rovers. I would also suggest articles on using CadSoft EAGLE, making PCBs, programming PICs in C.

I would also like to comment on your method for winding a coil. Winding in this way causes the wire to become twisted, leading to weak spots and kinks. The obvious way is to assemble the bobbin on a bolt as shown, but then insert this into a hand-drill or a power drill at slow speed. The wire will then feed off the reel without twisting.

Nigel Mercier, by email

Let's be quite clear, there is no right or wrong answer to this conundrum. One man's electronic meat is another's poison. Build-you-own hifi is a cornerstone of hobby electronics, and is consistently one of the most popular areas of project building – but it is not for everyone. We aim to cater for all tastes and ability levels – but we do listen to your opinions and thank you for writing to us.

Catch 'em young and keep 'em!

Dear Editor

I fondly remember issue 1 of *Everyday Electronics* and pestering my parents to buy it for me. This inspired further interest and I waited impatiently for the next issue to be available in the shops. The weeks between were filled with visits to local electronic surplus shops (now, sadly, few and far between) to find components to make circuits. My father was dragged with me to help fund this new obsession – actually, he seemed to enjoy it as much as me, which invariably meant that if I couldn't find my magazine, I knew where to look.

Time moves on and life takes you in many different directions, but electronics retains a strong influence on me, as it has done so for the last 25 years.

Recycle it! is excellent, but perhaps projects to use some of the recycled parts would be a good feature. A contest to make something from recycled parts would be fun.

Anything PIC is excellent. What about distant learning courses to gain some programming qualifications, since a lot of colleges do not offer these skills to young engineers who do not follow a degree course.

Teach-In 2011 will be very relevant to our apprentices starting their BTEC courses this month. A feature on interpreting schematic/wiring diagrams with actual components would be useful, since many apprentices seem to have problems grasping this concept.

A big 'thank you' for providing a broad interest magazine for both newcomers and experienced professionals – the company I work for has a subscription for staff. Keep up the good work; we need to capture the next generation in any way possible.

Malcolm Gale, Production Manager, JME Ltd, Lowestoft, Suffolk

Thank you too Malcolm for your encouraging words, and I am pleased to hear we are playing a part in teaching your apprentices.

PLT – the thin end of the wedge

Dear Editor

I was a bit annoyed by Mark Nelson's rather dismissive words about the use of power line transmission (PLT) and his suggestion that the shortwave spectrum is only used by a few radio amateurs and CB enthusiasts, and hence it didn't really matter too much in this day and age. Be that as may be, the new breed of gigabit PLTs (see the Belkin Gigabit powerline starter kit.) uses up to 300MHz, which could ruin FM broadcast, DAB and aeronautical services, as well as the amateur radio bands (see: **www.youtube.com/watch?v=z3yVu5IfaEY**).

PLT works well and generates minimum interference when the mains circuit offers a well-balanced load. Unfortunately, this is usually far from the situation with domestic mains wiring, and if switch-mode power supplies are on the same circuit then the radiation levels from a PLT may be raised by up to 20dB. Mains wiring and switch-mode power supplies are designed to work at 50Hz, not at VHF frequencies.

I recommend readers visit YouTube and do a search for PLT interference, or see the article in October's *Radio Communications* for some realistic tests. Last, do remember it is much cheaper, greener, faster and more secure to run a cable from a router to a distant PC than to use either PLT or Wi-Fi (another polluter of the spectrum!)

Mike Hastings, Hemel Hempstead

It's hard to disagree Mike, and let me assure you we meant no disrespect to radio amateurs and CB users. All spectrum space is a valuable resource and should be used properly and not polluted with noise.

From PICs to MS Excel

Dear Editor

I have written a program in JAL to read voltages from an RF antenna analyser and put them on an LCD display, but not knowing how to deal with squares, square roots and trigonometric functions on a PIC, I want to pass the data to a PC and Excel, where it can be processed and graphed.

I have been trying to find information on reading data into Excel via either an RS232 serial port or a USB port on a PC. I vaguely recollect articles in *EPE's Interface* column, and can find various vague mentions of this on the Internet pointing to *EPE* in 2002. Can you help?

Last, the *Digital LC Meter* (Mar '10) is an excellent new addition to my tool kit and is very useful.

Thank you for a magazine that I thoroughly enjoy reading.

Bob White G8SPC, by email

Any readers remember the article Bob Mentioned? Or perhaps you can simply tell him a simple way to pass data from a PIC to MS Excel.

Keep up the good work

Dear Editor

I have just received the September 2010 issue of *EPE* in today's post. It is a day I look forward to every month, just as I have way back to your first issue, and previously with the two separate magazines, *Practical Electronics* and *Everyday Electronics*. It has been one of my main sources of electronics-related information for many years. I started my first projects in electronics in my early teens during the 1960s, and I am still reliant on the magazine at my present age of 62 years.

I was incensed to read Tom Armitstead's 'Letter of the Month' in the September issue, complaining about 'too much PIC-related content' in *EPE*. I was more surprised when I read that he had been a keen reader of *EPE* almost as long as myself and admitted to being a lifelong professional programmer and software designer. I also have the same background, but only as a keen amateur (although I had a lifelong career in broadcast engineering). I started my assembler programming way back in the days of the SC/MP INS 8060 from National Semiconductor and eventually moved on through the Z80 route.

I followed the simply brilliant PIC assembly tutorials of my personal hero, the late John Becker, over several years. Thanks to these articles I have evolved into a capable programmer. I am not trying to blow my own trumpet here, I am simply highlighting that this knowledge is all down to the clear way John wrote on how assembly language could be used to interface to the outside world.

Only two days ago I mentioned to my wife, who is well seasoned to my projects by now, that 'my hero' is still supporting me through his articles even now, a year or so after his untimely death. I have just completed the construction of a prototype piece of equipment that uses several PIC microcontrollers from 8 to 40 pins. It is indeed a tribute to John and *EPE* that I have been able to design this from scratch into a fully working and stable project using mostly my own code. John always clearly explained the electronic circuitry involved in his articles, and gave hobbyists like myself the necessary electronics background needed to achieve this.

Had Tom Armitstead followed any of the same tutorials he would not have the opinion he presented in his letter. Like John Becker, I am perfectly capable of learning the variants of the C language that modern PIC programmers seem to prefer, but neither of us felt the need to spend the many hours needed to grasp such a language – for what we believed to be little gain. Having actually looked at C through the excellent articles written by Mike Hibbett and others, I find PIC assembler much more straightforward.

Tom also mentioned the PICAXE range of devices as a 'fresh alternative' for your magazine. I have no real problem encouraging youngsters and beginners of all ages to jump on the PIC bandwagon, but with the range of Microchip PIC devices now available, this would be a huge step backwards for the many seasoned PIC programmers who read *EPE*.

However, I would agree with Tom, who has every right to air his opinions in *Readout*, that some of the recent PIC projects can only be 'built' from the articles. The source code no longer seems to be available to study and learn from, unlike in the days of John Becker, when he used to clearly comment his coding, enabling us all to glean knowledge.

Having scratched my head and written long lines of assembler coding myself, I can understand why some of the recent authors want to protect their hard work, but sadly these projects no longer serve to educate us readers in the same way. This is a point which the editor might wish to comment on, and I appreciate it will not be an easy one to answer. Some of these otherwise excellent articles by several first-rate authors originate from the Australian *Silicon Chip* magazine.

One fact *EPE* cannot now get away from is that it has become the one journal that supports us PIC microcontroller users, both old and new. Your main competitor on the shelves here in the UK seems to be heavily biased towards Atmel devices, with precious few articles involving PIC chips. I hope the voice of one well-meaning reader will not persuade you to reduce the PIC content in *EPE*. These devices can be utilised in so many ways by anyone who gives them a modicum of attention, and the rewards in terms of satisfaction with the results of even simple experiments are high. Please keep up the good work on PIC devices, as well as all the other interesting and varied projects that I avidly read and often construct each month.

John Pugh, by email

Thank you John, Nigel and Tom, as well as others who have written on this or similar topics. We have to accept that PICs are not for everyone, but they are undoubtedly popular. It is not always possible to produce software listings, much as we would like to, since we are limited by space, copyright of the author and his or her willingness to write an explanation of the code.

Net Work

Alan Winstanley

Viral marketing

Regular *Net Work* readers will know that I visit the subject of anti-virus programs each year when it's time to review my software licences. After noticing how my expiring anti-virus program was grinding ever more slowly in the background, and frequently consuming 50% of PC resources, I decided to try my luck elsewhere, so after a reasonable trial period I settled on AVG Anti-Virus. I have definitely noticed how my PC has perked up a little.

There is really no excuse for not running an up-to-date AV program. Apart from anything, a regular scan will help ensure your machine is not infected with a Trojan that is silently sending out thousands of spams, or taking part in a denial of service attack, without your knowledge. For home use, I feel there is nothing better than the free edition of AVG (download from **http://free.avg.com**). It offers anti-virus, anti-spyware and anti root-kit protection, along with those all-important regular updates, together with a 'Link Scanner' check in real time when you access web pages. This latter feature displays an idiot-proof confidence-boosting green tick symbol alongside search results. A quick mouse-over produces a popup with more information, which turns amber or red depending on AVG's analysis of the potential threat.

type your IMEI or SIM numbers into the useful International Numbering Plans website (**www.numberingplans.com**) to view the details. More general guidance about mobile phone theft is offered by the Mobile Phone Crime Unit at **www.met.police.uk/mobilephone**.

One point to remember is that if the phone also connects via Wi-Fi, then even if the service provider blocks the phone and SIM card, it could still fetch emails. A screen timeout would however bar access and require the PIN number after a certain period had elapsed, and this might be the only protection you have.

Refreshingly, my phone was handed in by an honest member of the public and I was reunited with it a day or two later. The loss of my phone did however force me to reassess my mobile data security and privacy risks. My phone was running F-Secure Anti-Theft for Mobile, a phone locking and data wiping program that can be activated by sending it a text message containing a secret code. It can also send an alert if the SIM card is changed. This software is now free and can be downloaded directly onto your Windows Mobile 6+, Symbian or Android phone and certain others from **http://mobile.f-secure.com** or via the website at **www.f-secure.com.** You can update your phone through USB or Bluetooth. It is not yet available for iPhone.

(above) AVG LinkScanner displays a reassuring green tick against search links that it considers are safe

(far right) F-Secure Mobile Security is a free download for most phones and locks or wipes data when you send an SMS

The paid-for versions of AVG offer more online protection, with firewalls and online chat protection, (eg, when exchanging files with other users) together with full technical support. Discounts are available for extended subscriptions covering several computers, but when searching out the best deal for multiple licences on a two-year subscription, I found the AVG website was rather non-intuitive and I had to hunt around before landing on the correct area.

Phone home…

Having nailed down the problem of choosing anti-virus protection on my PCs for another year, my attention turned to my mobile phone under some rather fraught circumstances. A few days ago I had the misfortune of losing my HTC smartphone in a supermarket car park. As the phone is configured to check emails on the move, I realised that I had a potential security and privacy problem on my hands. I raced to find a landline and called the phone provider who blocked the phone and the SIM card, rendering each unusable, although the shut-down process takes time to trickle through the network.

Each mobile phone has an IMEI (International Mobile Equipment Identity) number that can usually be read by dialling *#06#, or there may be a sticker underneath the battery; it's a code that you should ideally carry with you in case you need to report a loss to the police. You can

I had purchased an earlier version of F-Secure Anti-Theft for Mobile when it was a paid-for product. I downloaded the latest version over the web onto the phone's MicroSD card and the program proceeded to uninstall my older (paid-for) copy. Uninstalling a small program or two freed up some memory headroom for successful activation via Wi-Fi (as my phone was still locked). After installation, you select the Anti-Theft settings (Enable Locate, Wipe and/or Lock as desired) and punch in your own security code. This can be texted to the phone to activate the appropriate command.

I have yet to test the SMS features (especially the Locate option, which reports the phone's position on a map), but if your phone is compatible with the program then F-Secure Mobile Security is a definite download worth trying. Other paid-for programs available include Kaspersky Mobile Security 9 and Trend Micro Mobile Security. A little bit of advanced planning could help save an enormous amount of hassle and crisis management if like me, you suddenly find one day that your phone has been misplaced or stolen.

See you next month for more *Net Work*. I'm always pleased to receive feedback. I read every email and I am sorry if I cannot always reply individually. You can email me at **alan@epemag.demon.co.uk** or write to the editor at **editorial@wimborne.co.uk**.

NEW

Electronics Teach-In 3

FREE CD-ROM

The three sections of this book cover a very wide range of subjects that will interest everyone involved in electronics, from hobbyists and students to professionals. The first 80-odd pages of Teach-In 3 are dedicated to *Circuit Surgery*, the regular *EPE* clinic dealing with readers' queries on various circuit design and application problems – everything from voltage regulation to using SPICE circuit simulation software.

The second section – *Practically Speaking* – covers the practical aspects of electronics construction. Again, a whole range of subjects, from soldering to avoiding problems with static electricity and indentifying components, are covered.

Finally, our collection of *Ingenuity Unlimited* circuits provides over 40 different circuit designs submitted by the readers of *EPE*.

The free cover-mounted CD-ROM is the complete *Electronics Teach-In 1* book, which provides a broad-based introduction to electronics in PDF form, plus interactive quizzes to test your knowledge, TINA circuit simulation software (a limited version – plus a specially written TINA Tutorial), together with simulations of the circuits in the Teach-In 1 series, plus Flowcode (a limited version) a high level programming system for PIC microcontrollers based on flowcharts.

The Teach-In 1 series covers everything from Electric Current through to Microprocessors and Microcontrollers and each part includes demonstration circuits to build on breadboards or to simulate on your PC. There is also a MW/LW Radio project in the series.

The contents of the book and Free CD-ROM have been reprinted from past issues of *EPE*.

160 pages+CD-ROM **Order code ET3** £8.50

DIRECT BOOK SERVICE

The books listed have been selected by *Everyday Practical Electronics* editorial staff as being of special interest to everyone involved in electronics and computing. They are supplied by mail order direct to your door. Full ordering details are given on the last book page.

FOR A FURTHER SELECTION OF BOOKS SEE THE NEXT TWO ISSUES OF *EPE*

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All prices include UK postage

RADIO

BASIC RADIO PRINCIPLES AND TECHNOLOGY
Ian Poole

Radio technology is becoming increasingly important in today's high technology society. There are the traditional uses of radio which include broadcasting and point to point radio as well as the new technologies of satellites and cellular phones. All of these developments mean there is a growing need for radio engineers at all levels.

Assuming a basic knowledge of electronics, this book provides an easy to understand grounding in the topic.

Chapters in the book: Radio Today, Yesterday, and Tomorrow; Radio Waves and Propagation; Capacitors, Inductors, and Filters; Modulation; Receivers; Transmitters; Antenna Systems; Broadcasting; Satellites; Personal Communications; Appendix – Basic Calculations.

263 pages **Order code NE30** £28.99

PROJECTS FOR RADIO AMATEURS AND S.W.L.S.
R. A. Penfold

This book describes a number of electronic circuits, most of which are quite simple, which can be used to enhance the performance of most short wave radio systems.

The circuits covered include: An aerial tuning unit; A simple active aerial; An add-on b.f.o. for portable sets; A wavetrap to combat signals on spurious responses; An audio notch filter; A parametric equaliser; C.W. and S.S.B. audio filters; Simple noise limiters; A speech processor; A volume expander.

Other useful circuits include a crystal oscillator, and RTTY/C.W. tone decoder, and a RTTY serial to parallel converter. A full range of interesting and useful circuits for short wave enthusiasts.

92 pages **Order code BP304** £4.45

AN INTRODUCTION TO AMATEUR RADIO
I. D. Poole

Amateur radio is a unique and fascinating hobby which has attracted thousands of people since it began at the turn of the last century. This book gives the newcomer a comprehensive and easy to understand guide through the subject so that the reader can gain the most from the hobby. It then remains an essential reference volume to be used time and again. Topics covered include the basic aspects of the hobby, such as operating procedures, jargon and setting up a station. Technical topics covered include propagation, receivers, transmitters and aerials etc.

150 pages **Order code BP257** £5.49

ROBOTICS

INTRODUCING ROBOTICS WITH LEGO MINDSTORMS
Robert Penfold

Shows the reader how to build a variety of increasingly sophisticated computer controlled robots using the brilliant Lego Mindstorms Robotic Invention System (RIS). Initially covers fundamental building techniques and mechanics needed to construct strong and efficient robots using the various "click-together" components supplied in the basic RIS kit. Then explains in simple terms how the "brain" of the robot may be programmed on screen using a PC and "zapped" to the robot over an infra-red link. Also, shows how a more sophisticated Windows programming language such as Visual BASIC may be used to control the robots.

Detailed building and programming instructions provided, including numerous step-by-step photographs.

288 pages - large format **Order code BP901** £14.99

MORE ADVANCED ROBOTICS WITH LEGO MINDSTORMS – Robert Penfold

Shows the reader how to extend the capabilities of the brilliant Lego Mindstorms Robotic Invention System (RIS) by using lego's own accessories and some simple home constructed units. You will be able to build robots that can provide you with 'waiter service' when you clap your hands, perform tricks, 'see' and avoid objects by using 'bats radar', or accurately follow a line marked on the floor. Learn to use additional types of sensors including rotation, light, temperature, sound and ultrasonic and also explore the possibilities provided by using an additional (third) motor. For the less experienced, RCX code programs accompany most of the featured robots. However, the more adventurous reader is also shown how to write programs using Microsoft's VisualBASIC running with the ActiveX control (Spirit.OCX) that is provided with the RIS kit.

Detailed building instructions are provided for the featured robots, including numerous step-by-step photographs. The designs include rover vehicles, a virtual pet, a robot arm, an 'intelligent' sweet dispenser and a colour conscious robot that will try to grab objects of a specific colour.

198 pages **Order code BP902** £14.99

ANDROIDS, ROBOTS AND ANIMATRONS
Second Edition – John Iovine

Build your own working robot or android using both off-the-shelf and workshop constructed materials and devices. Computer control gives these robots and androids two types of artificial intelligence (an expert system and a neural network). A lifelike android hand can be built and programmed to function doing repetitive tasks. A fully animated robot or android can also be built and programmed to perform a wide variety of functions.

The contents include an Overview of State-of-the-Art Robots; Robotic Locomotion; Motors and Power Controllers; All Types of Sensors; Tilt; Bump; Road and Wall Detection; Light; Speech and Sound Recognition; Robotic Intelligence (Expert Type) Using a Single-Board Computer Programmed in BASIC; Robotic Intelligence (Neutral Type) Using Simple Neural Networks (Insect Intelligence); Making a Lifelike Android Hand; A Computer-Controlled Robotic Insect Programmed in BASIC; Telepresence Robots With Actual Arcade and Virtual Reality Applications; A Computer-Controlled Robotic Arm; Animated Robots and Androids; Real-World Robotic Applications.

224 pages **Order code MGH1** £16.99

COMPUTERS AND COMPUTING

ELECTRONICS TEACH-IN 2 CD-ROM

USING PIC MICROCONTROLLERS A PRACTICAL INTRODUCTION

This *Teach-In* series of articles was originally published in *EPE* in 2008 and, following demand from readers, has now been collected together in the *Electronics Teach-In 2* CD-ROM.

The series is aimed at those using PIC microcontrollers for the first time. Each part of the series includes breadboard layouts to aid understanding and a simple programmer project is provided.

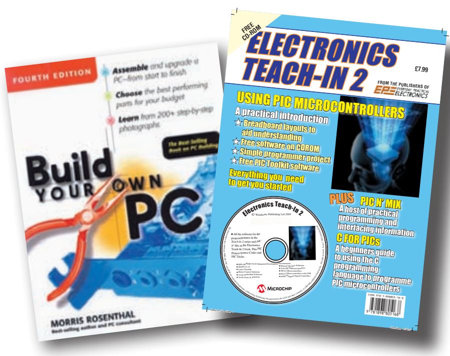
Also included are 29 *PIC N' Mix* articles, also republished from *EPE*. These provide a host of practical programming and interfacing information, mainly for those that have already got to grips with using PIC microcontrollers.

An extra four part beginners guide to using the C programing language for PIC microcontrollers is also included.

The CD-ROM also contains all of the software for the *Teach-In 2* series and *PIC N' Mix* articles, plus a range of items from Microchip – the manufacturers of the PIC microcontrollers. The material has been compiled by Wimborne Publishing Ltd. with the assistance of Microchip Technology Inc.

The Microchip items are: MPLAB Integrated Development Environment V8.20; Microchip Advance Parts Selector V2.32; Treelink; Motor Control Solutions; 16-bit Embedded Solutions; 16-bit Tool Solutions; Human Interface Solutions; 8-bit PIC Microcontrollers; PIC24 Mircontrollers; PIC32 Microcontroller Family with USB On-The-Go; dsPIC Digital Signal Controllers.

CD-ROM **Order code ETI2 CD-ROM** £9.50



BUILD YOUR OWN PC – Fourth Edition
Morris Rosenthal

More and more people are building their own PCs. They get more value for their money, they create exactly the machine they want, and the work is highly satisfying and actually fun. That is, if they have a unique beginner's guide like this one, which visually demonstrates how to construct a computer from start to finish.

Through 150 crisp photographs and clear but minimal text, readers will confidently absorb the concepts of computer building. The extra-big format makes it easy to see what's going on in the pictures. The author goes 'under the hood' and shows step-by-step how to create a Pentium 4 computer or an Athlon 64 or Athlon 64FX, covering: What first-time builders need to know; How to select and purchase parts; How to assemble the PC; How to install Windows XP. The few existing books on this subject, although outdated, are in steady demand. This one delivers the expertise and new technology that fledgling computer builders are looking for.

224 pages - large format **Order code MGH2** £16.99

PROGRAMMING 16-BIT PIC MICROCONTROLLERS IN C – LEARNING TO FLY THE PIC24 Lucio Di Jasio (Application Segments Manager, Microchip, USA)

A Microchip insider tells all. Focuses on examples and exercises that show how to solve common, real-world design problems quickly. Includes handy checklists to help readers perform the most common programming and debugging tasks. FREE CD-ROM includes source code in C, the Microchip C30 compliler, and MPLAB SIM software, so that readers gain practical, hands-on programming experience.

Until recently, PICs didn't have the speed and memory necessary for use in designs such as video- and audio-enabled devices. All that changed with the introduction of the 16-bit PIC family, the PIC24. This new guide teaches readers everything they need to know about the architecture of these chips, how to program them, how to test them and how to debug them. Lucio's common-sense, practical, hands-on approach starts out with basic functions and guides the reader step-by-step through even the most sophisticated programming scenarios.

Experienced PIC users and newcomers alike will benefit from the text's many thorough examples, which demonstrate how to nimbly side-step common obstacles and take full advantage of all the 16-bit features.

496 pages +CD-ROM **Order code NE45** £38.00

NEW FULL COLOUR COMPUTING BOOKS

WINDOWS 7 – TWEAKS, TIPS AND TRICKS
Andrew Edney

This book will guide you through many of the exciting new features of Windows 7. Microsoft's latest and greatest operating system. It will provide you with useful hints, tips and warnings about possible difficulties and pitfalls. This book should enable you to get much more out of Windows 7 and, hopefully, discover a few things that you may not have realised were there.

Among the topics covered are: A brief overview of the various versions of Windows 7. How to install and use Upgrade Advisor, which checks to see if your computer meets the minimum requirements to run Windows 7 and that your software and drivers are supported by Windows 7. How to use Windows Easy Transfer to migrate your data and settings from your Vista or XP machine to your new Windows 7 computer. Exploring Windows 7 so that you will become familiar with many of its new features and then see how they contrast with those of earlier versions of Windows. How to connect to a network and create and use Home Groups to easily share your pictures, videos, documents, etc.,with the minimum of hassle. Why Windows Live Essentials is so useful and how to download and install it. A brief introduction to Windows Media Center. The use of Action Center, which reports security and maintenance incidents. Windows Memory Diagnostic to detect the fairly common problem of faulty memory and Troubleshooting tools.

120 pages **Order code BP708** **£8.49**

HOW TO BUILD A COMPUTER MADE EASY
R.A. Penfold

Building your own computer is a much easier than most people realise and can probably be undertaken by anyone who is reasonably practical. However, some knowledge and experience of using a PC would be beneficial. This book will guide you through the entire process. It is written in a simple and straightforward way with the explanations clearly illustrated with numerous colour photographs.

The book is divided into three sections: *Overview and preparation* – Covers understanding the fundamentals and choosing the most suitable component parts for your computer, together with a review of the basic assembly. *Assembly* – Explains in detail how to fit the component parts into their correct positions in the computer's casing, then how to connect these parts together by plugging the cables into the appropriate sockets. No soldering should be required and the only tools that you are likely to need are screwdrivers, small spanners and a pair of pliers.

BIOS and operating system – This final section details the setting up of the BIOS and the installation of the Windows operating system, which should then enable all the parts of your computer to work together correctly. You will then be ready to install your files and any application software you may require.

The great advantage of building your own computer is that you can 'tailor' it exactly to your own requirements. Also, you will learn a tremendous amount about the structure and internal workings of a PC, which will prove to be invaluable should problems ever arise.

120 pages **Order code BP707** **£8.49**

AN INTRDUCTION TO eBAY FOR THE OLDER GENERATION
Cherry Nixon

eBay is an online auction site that enables you to buy and sell practically anything from the comfort of your own home. eBay offers easy access to the global market at an amazingly low cost and will enable you to turn your clutter into cash.

This book is an introduction to eBay.co.uk and has been specifically written for the over 50s who have little knowledge of computing. The book will, of course, also apply equally to all other age groups. The book contains ideas for getting organised for long term safe and successful trading. You will learn how to search out and buy every conceivable type of thing.The book also shows you how to create auctions and add perfect pictures. There is advice on how to avoid the pitfalls that can befall the inexperienced.

Cherry Nixon is probably the most experienced teacher of eBay trading in the UK and from her vast experience has developed a particular understanding of the issues and difficulties normally encountered by individuals.

So, if you are new to computers and the internet and think of a mouse as a rodent, then this is the book for you!

120 pages **Order code BP709** **£8.49**

GETTING STARTED IN COMPUTING FOR THE OLDER GENERATION
Jim Gatenby

You can learn to use a computer at any age and this book will help you acheive this. It has been especially written for the over 50s, using plain English and avoiding technical jargon wherever possible. It is lavishly illustrated in full colour.

Among the many practical and useful subjects that are covered in this book are: Choosing the best computing system for your needs. Understanding the main hardware components of your computer. Getting your computer up and runnning in your home. Setting up peripheral devices like printers and routers. Connecting to the internet using wireless broadband in a home with one or more computers. Getting familiar with Windows Vista and XP the software used for operating and maintaining your computer. Learning about Windows built-in programs such as Windows Media Player, Paint and Photo Gallery.

Plus, using the Ease of Access Center to help if you have impaired eyesight, hearing or dexterity problems. Installing and using essential software such as Microsoft Office suite. Searching for the latest information on virtually any subject. Keeping in touch with friends and family using e-mail. Keeping your computer running efficiently and your valuable data files protected against malicious attack.

This book will help you to gain the basic knowledge needed to get the most out of your computer and, if you so wish, give you the confidence to even join a local computer class.

120 pages **Order code BP704** **£8.49**

THEORY AND REFERENCE

ELECTRONIC CIRCUITS – FUNDAMENTALS & APPLICATIONS
Third Edition
Mike Tooley

A comprehensive reference text and practical electronics handbook in one volume – at an affordable price!

New chapter on PIC microcontrollers – the most popular chip family for use in project work by hobbyists and in colleges and universities.

New companion website: spreadsheet design tools to simplify circuit calculations; circuit models and templates to enable virtual simulation; a bank of on-line questions for lecturers to set as assignments, and on-line self-test multiple choice questions for each chapter with automatic marking, to enable students to continually monitor their progress and understanding.

The book's content is matched to the latest pre-degree level courses, making this an invaluable reference for all study levels, and its broad coverage is combined with practical case studies, based in real-world engineering contexts throughout the text.

The unique combination of a comprehensive reference text, incorporating a primary focus on practical applications, ensures this text will prove a vital guide for students and also for industry-based engineers, who are either new to the field of electronics, or who wish to refresh their knowledge.

400 pages **Order code NE43** **£25.99**

BEBOP TO THE BOOLEAN BOOGIE
Third Edition
Clive (Max) Maxfield

This book gives the 'big picture' of digital electronics. This indepth, highly readable, guide shows you how electronic devices work and how they're made. You'll discover how transistors operate, how printed circuit boards are fabricated, and what the innards of memory ICs look like. You'll also gain a working knowledge of Boolean Algebra and Karnaugh Maps, and understand what Reed-Muller logic is and how it's used. And there's much, MUCH more. The author's tongue-in-cheek humour makes it a delight to read, but this is a REAL technical book, extremely detailed and accurate.

Contents: Fundamental concepts; Analog versus digital; Conductors and insulators; Voltage, current, resistance, capacitance and inductance; Semiconductors; Primitive logic functions; Binary arithmetic; Boolean algebra; Karnaugh maps; State diagrams, tables and machines; Analog-to-digital and digital-to-analog; Integrated circuits (ICs); Memory ICs; Programmable ICs; Application-specific integrated circuits (ASICs); Circuit boards (PWBs and DWBs); Hybrids; Multichip modules (MCMs); Alternative and future technologies.

500 pages **Order code BEB1** **£32.99**

BEBOP BYTES BACK (and the Beboputer Computer Simulator) CD-ROM
Clive (Max) Maxfield and Alvin Brown

This follow-on to Bebop to the Boolean Boogie is a multimedia extravaganza of information about how computers work. It picks up where "Bebop I" left off, guiding you through the fascinating world of computer design . . . and you'll have a few chuckles, if not belly laughs, along the way. In addition to over 200 megabytes of mega-cool multimedia, the CD-ROM contains a virtual microcomputer, simulating the motherboard and standard computer peripherals in an extremely realistic manner. In addition to a wealth of technical information, myriad nuggets of trivia, and hundreds of carefully drawn illustrations, the CD-ROM contains a set of lab experiments for the virtual microcomputer that let you recreate the experiences of early computer pioneers. if you're the slightest bit interested in the inner workings of computers, then don't dare to miss this!

Over 800 pages in Adobe Acrobat format

CD-ROM **Order code BEB2 CD-ROM** **£21.95**

FUNDAMENTAL ELECTRICAL AND ELECTRONIC PRINCIPLES
Third Edition
C. R. Robertson

Covers the essential principles that form the foundations for electrical and electronic engineering courses. The coverage of this new edition has been carefully brought in line with the core unit 'Electrical and Electronic Principles' of the 2007 BTEC National Engineering specification. This qualification from Edexcel attracts more than 10,000 students per year.

The book explains all theory in detail and backs it up with numerous worked examples. Students can test their understanding with end of chapter assignment questions for which answers are provided. In this new edition, the layout has been improved and colour has been added. A free companion website with additional worked examples and chapters is also available.

368 pages **Order code NE47** **£21.99**

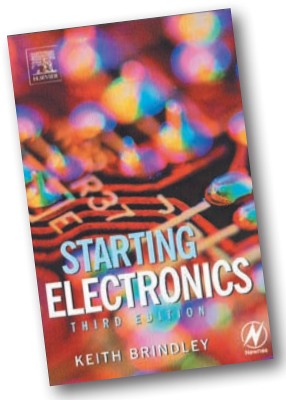
STARTING ELECTRONICS
Third Edition
Keith brindley

A punchy practical introduction to self-build electronics. The ideal starting point for home experimenters, technicians and students who want to develop the real hands-on skills of electronics construction.

A highly practical introduction for hobbyists, students, and technicians. Keith Brindley introduces readers to the functions of the main component types, their uses, and the basic principles of building and designing electronic circuits.

Breadboard layouts make this very much a ready-to-run book for the experimenter, and the use of multimeter, but not oscilloscopes, and readily available, inexpensive components makes the practical work achievable in a home or school setting as well as a fully equiped lab.

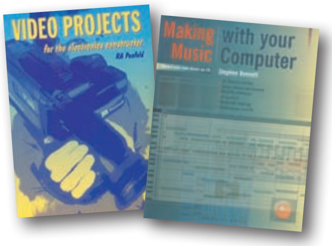
Temporarily out of print



MUSIC, AUDIO AND VIDEO

MAKING MUSIC WITH YOUR COMPUTER
Stephen Bennett
Nearly everyone with musical aspirations also has a computer. This same computer can double as a high quality recording studio capable of producing professional recordings. This book tells you what software and hardware you will need to get the best results.
You'll learn about recording techniques, software and effects, mixing, mastering and CD production.
Suitable for PC and Mac users, the book is full of tips, "how to do" topics and illustrations. It's the perfect answer to the question "How do I use my computer to produce my own CD?"

92 pages **Order code PC120** **£10.95**



QUICK GUIDE TO MP3 AND DIGITAL MUSIC
Ian Waugh
MP3 files, the latest digital music format, have taken the music industry by storm. What are they? Where do you get them? How do you use them? Why have they thrown record companies into a panic? Will they make music easier to buy? And cheaper? Is this the future of music?
All these questions and more are answered in this concise and practical book which explains everything you need to know about MP3s in a simple and easy-to-understand manner. It explains:
How to play MP3s on your computer; How to use MP3s with handheld MP3 players; Where to find MP3s on the Web; How MP3s work; How to tune into Internet radio stations; How to create your own MP3s; How to record your own CDs from MP3 files; Other digital audio music formats.
Whether you want to stay bang up to date with the latest music or create your own MP3s and join the on-line digital music revolution, this book will show you how.

60 pages **Order code PC119** **£7.45**

VIDEO PROJECTS FOR THE ELECTRONICS CONSTRUCTOR
R. A. Penfold
Written by highly respected author R. A. Penfold, this book contains a collection of electronic projects specially designed for video enthusiasts. All the projects can be simply constructed, and most are suitable for the newcomer to project construction, as they are assembled on stripboard.
There are faders, wipers and effects units which will add sparkle and originality to your video recordings, an audio mixer and noise reducer to enhance your soundtracks and a basic computer control interface. Also, there's a useful selection on basic video production techniques to get you started.
Complete with explanations of how the circuit works, shopping lists of components, advice on construction, and guidance on setting up and using the projects, this invaluable book will save you a small fortune.
Circuits include: video enhancer, improved video enhancer, video fader, horizontal wiper, improved video wiper, negative video unit, fade to grey unit, black and white keyer, vertical wiper, audio mixer, stereo headphone amplifier, dynamic noise reducer, automatic fader, pushbutton fader, computer control interface, 12 volt mains power supply.

124 pages **Order code PC115** ~~£10.95~~ **£5.45**

RADIO BYGONES
We also carry a selection of books aimed at readers of *EPE*'s sister magazine on vintage radio *Radio Bygones*. These books include, the four volumes of our own *Wireless For the Warrior* by Louis Meulstee. These are a technical history of radio communication equipment in the British Army and clandestine equipment from pre-war through to the 1960s.
For details see the UK shop on our web site at www.epemag.com or contact us for a list of *Radio Bygones* books.

PROJECT BUILDING AND TESTING

ELECTRONIC PROJECT BUILDING FOR BEGINNERS
R. A. Penfold
This book is for complete beginners to electronic project building. It provides a complete introduction to the practical side of this fascinating hobby, including the following topics:
Component identification, and buying the right parts; resistor colour codes, capacitor value markings, etc; advice on buying the right tools for the job; soldering; making easy work of the hard wiring; construction methods, including stripboard, custom printed circuit boards, plain matrix boards, surface mount boards and wire-wrapping; finishing off, and adding panel labels; getting "problem" projects to work, including simple methods of fault-finding.
In fact everything you need to know in order to get started in this absorbing and creative hobby.

135 pages **Order code BP392** **£5.99**

BUILDING VALVE AMPLIFIERS
Morgan Jones
The practical guide to building, modifying, fault-finding and repairing valve amplifiers. A hands-on approach to valve electronics – classic and modern – with a minimum of theory. Planning, fault-finding, and testing are each illustrated by step-by-step examples.
A unique hands-on guide for anyone working with valve (tube in USA) audio equipment – as an electronics experimenter, audiophile or audio engineer.
Particular attention has been paid to answering questions commonly asked by newcomers to the world of the vacuum tube, whether audio enthusiasts tackling their first build, or more experienced amplifier designers seeking to learn the ropes of working with valves. The practical side of this book is reinforced by numerous clear illustrations throughout.

368 pages **Order code NE40** **£29.00**

PRACTICAL FIBRE-OPTIC PROJECTS
R. A. Penfold
While fibre-optic cables may have potential advantages over ordinary electric cables, for the electronics enthusiast it is probably their novelty value that makes them worthy of exploration. Fibre-optic cables provide an innovative interesting alternative to electric cables, but in most cases they also represent a practical approach to the problem. This book provides a number of tried and tested circuits for projects that utilize fibre-optic cables.
The projects include:- Simple audio links, F.M. audio link, P.W.M. audio links, Simple d.c. links, P.W.M. d.c. link, P.W.M. motor speed control, RS232C data links, MIDI link, Loop alarms, R.P.M. meter.
All the components used in these designs are readily available, none of them require the constructor to take out a second mortgage.

132 pages **Order code BP374** **£5.45**

GETTING THE MOST FROM YOUR MULTIMETER
R. A. Penfold
This book is primarily aimed at beginners and those of limited experience of electronics. Chapter 1 covers the basics of analogue and digital multimeters, discussing the relative merits and the limitations of the two types. In Chapter 2 various methods of component checking are described, including tests for transistors, thyristors, resistors, capacitors and diodes. Circuit testing is covered in Chapter 3, with subjects such as voltage, current and continuity checks being discussed.
In the main little or no previous knowledge or experience is assumed. Using these simple component and circuit testing techniques the reader should be able to confidently tackle servicing of most electronic projects.

102 pages **Order code BP239** **£5.49**

BOOK ORDERING DETAILS
All prices include UK postage. For postage to Europe (air) and the rest of the world (surface) please add £3 per book. Surface mail can take up to 10 weeks to some countries. For the rest of the world airmail add £4 per book. CD-ROM prices include VAT and/or postage to anywhere in the world. Send a PO, cheque, international money order (£ sterling only) made payable to **Direct Book Service** or card details, Visa, Mastercard or Maestro to: **DIRECT BOOK SERVICE, WIMBORNE PUBLISHING LIMITED, 113 LYNWOOD DRIVE, MERLEY, WIMBORNE, DORSET BH21 1UU**.

Books are normally sent within seven days of receipt of order, but please allow 28 days for delivery – more for overseas orders. *Please check price and availability (see latest issue of* Everyday Practical Electronics*) before ordering from old lists.*

For a further selection of books see the next two issues of *EPE*.
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PCB SERVICE

Printed circuit boards for most recent *EPE* constructional projects are available from the *PCB Service*, see list. These are fabricated in glass fibre, and are fully drilled and roller tinned. Double-sided boards are **NOT plated through hole** and will require 'vias' and some components soldering to both sides. All prices include VAT and postage and packing. Add £1 per board for airmail outside of Europe. Remittances should be sent to **The PCB Service, Everyday Practical Electronics, Wimborne Publishing Ltd., 113 Lynwood Drive, Merley, Wimborne, Dorset BH21 1UU. Tel: 01202 880299; Fax 01202 843233; Email: orders@epemag.wimborne.co.uk. On-line Shop: www.epemag.com**. Cheques should be crossed and made payable to *Everyday Practical Electronics* **(Payment in £ sterling only)**.

NOTE: While 95% of our boards are held in stock and are dispatched within seven days of receipt of order, please allow a maximum of 28 days for delivery – overseas readers allow extra if ordered by surface mail.

Back numbers or photocopies of articles are available if required – see the Back Issues page for details. WE DO NOT SUPPLY KITS OR COMPONENTS FOR OUR PROJECTS.

Please check price and availability in the latest issue.
A large number of older boards are listed on, and can be ordered from, our website.

Boards can only be supplied on a payment with order basis.

PROJECT TITLE	ORDER CODE	COST
OCTOBER '09		
1pps Driver for Quartz Clocks	725	£5.71
Minispot 455kHz Modulated Oscillator	726	£5.87
Prog. Ignition System for Cars		
– Ignition Unit	727 } set	£11.10
– Ignition Coil Driver	728	
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Class-A Headphone Amplifier		
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– PSU	732	
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★ Water Tank Level Meter	753	£6.66
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– Adaptor	755	
JUNE '10		
★ PIC-Based Musical Tuning Aid	756	£8.24
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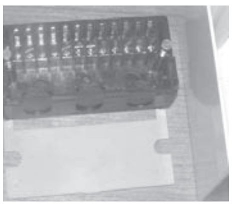

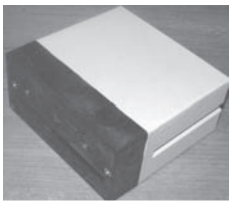

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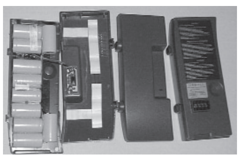

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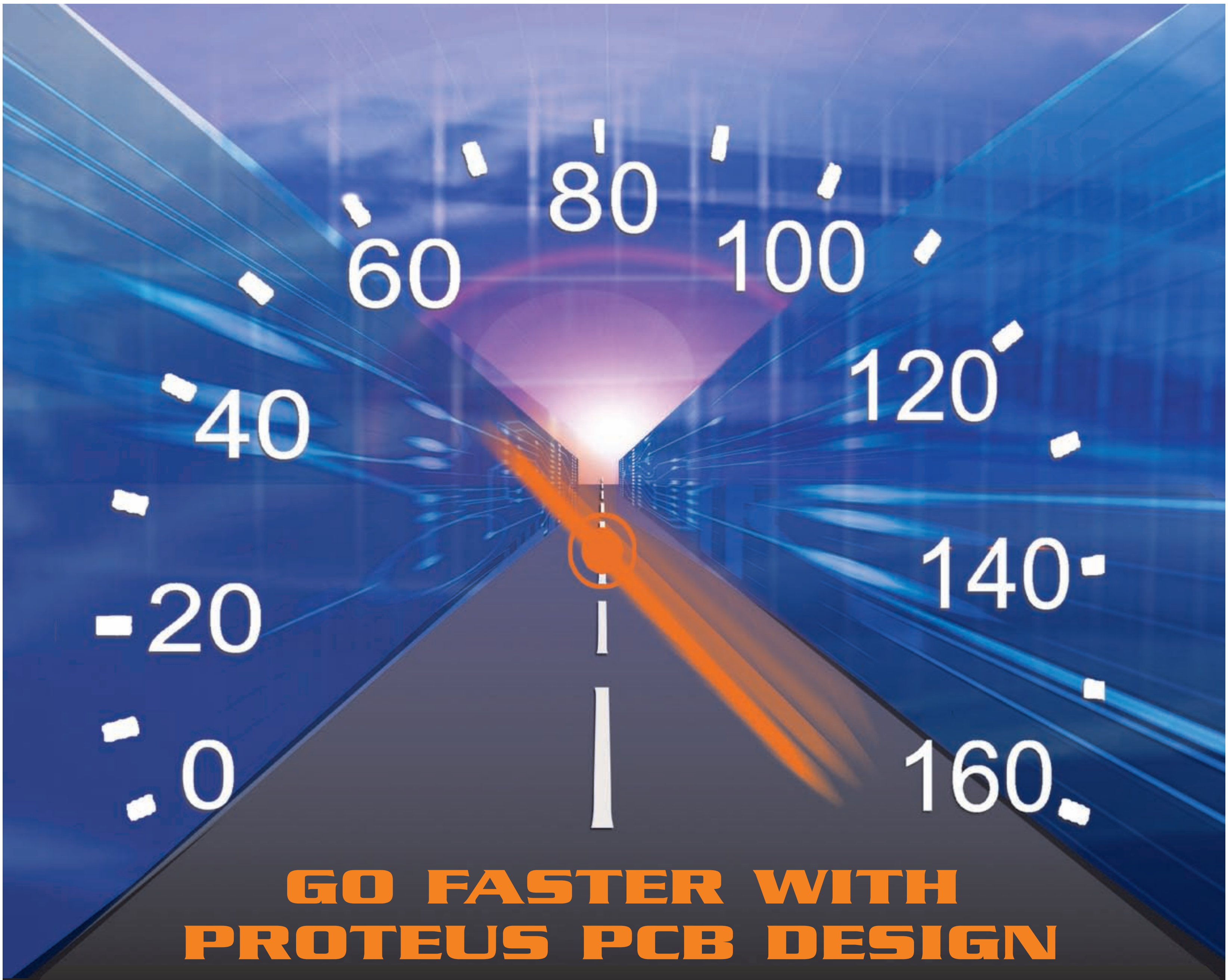

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